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CENTRAL AIRBORNE PERFORMANCE ANALYZER.(U)

MAR 69 J E BARKER, W L KRUSE, G J MROS F33657-67-C-0743

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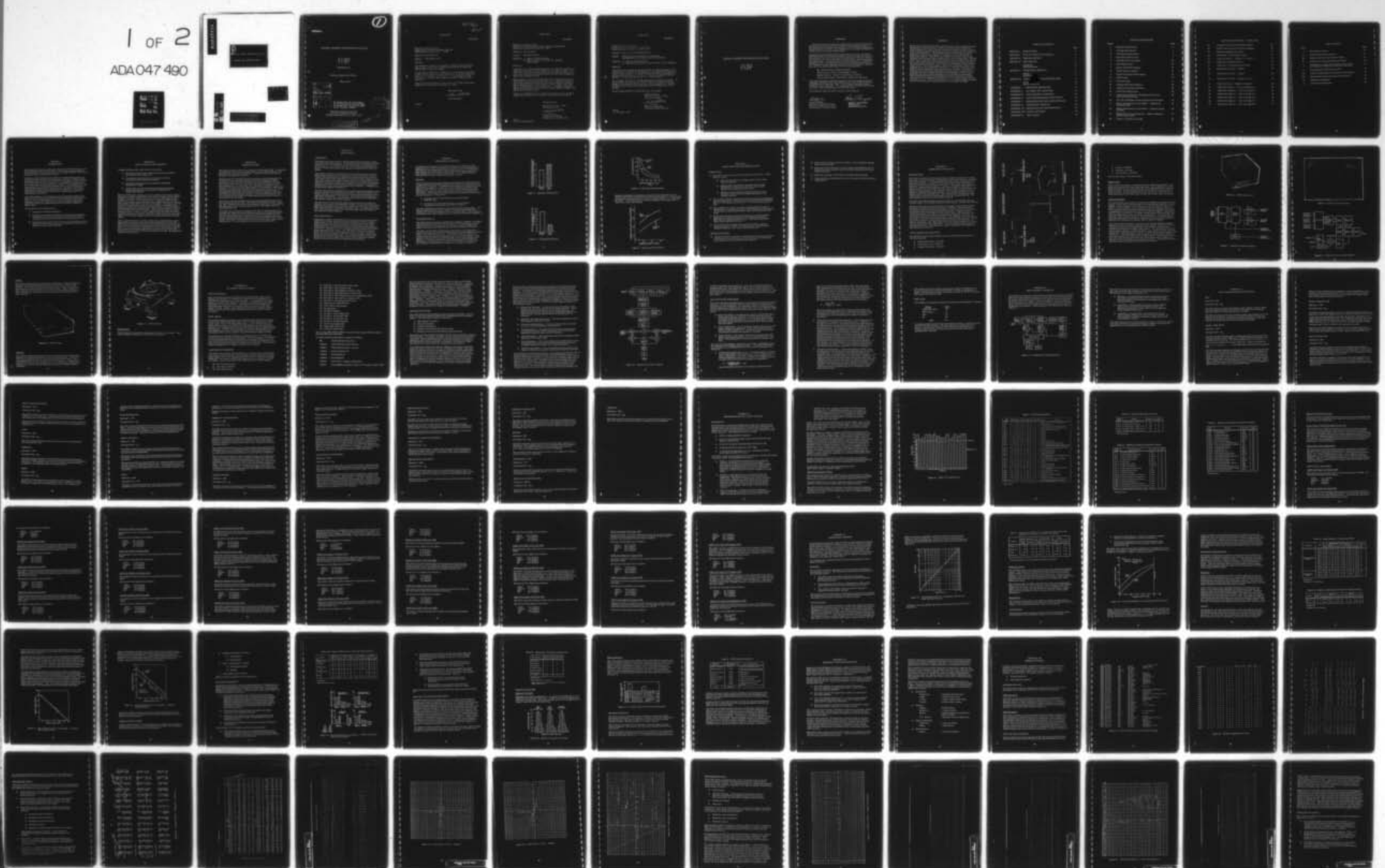

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CENTRAL AIRBORNE PERFORMANCE ANALYZER

J. E. Barker
W. L. Kruse
G. J. Mros

Honeywell Inc.

Technical Report ASD-TR-68-

March 1969

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RE: ASD TR Report No. for document--
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per Mr. Leightey, ASD/AER

Aeronautical Systems Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

See 1473

Paul Mayo

R3-368

4 April 1969

ASE-690229

Department of the Air Force
Headquarters, Aeronautical Systems Division
Wright-Patterson A.F.B., Ohio 45433

Attention: Mr. Leo Gambone

Subject: CAPA Final Report

Dear Leo:

I am writing to send you a few copies of the CAPA Final Report for your own use. I have made a formal transmittal of the report to ASD and TARC under separate cover.

I would like to thank you, on behalf of all of us here at Honeywell, for your wholehearted support and cooperation during the Feasibility Demonstration Program. I have enjoyed working with you on this CAPA program, and I am looking forward to working with you on the next one.

If you need any more copies, or if I can be of service on some other matter, please don't hesitate to give me a call.

Sincerely yours,

Tom Whittaker

T. A. Whittaker

TAW:smh

4 April 1969

ASE-690227

Department of the Air Force
Headquarters USAF Tactical Air Reconnaissance Center (TARC)
Shaw Air Force Base, South Carolina 29152

Attention: Mr. Tom Julian

Subject: CAPA Final Report

Reference: 1. Contract F33657-67-C-0743
2. Letter from R.P. Hickey to T.A. Whittaker dated 2-13-69

Gentlemen:

I am writing to transmit three (3) copies of the CAPA Final Report, as required by data item A010 of Exhibit A to the subject contract. The report has been prepared in accordance with Paragraphs 3.3.8., 3.6.5., 3.7., 3.8., and 6.4.10. of contract exhibit SEQ 65-9, and approved, by ASD, in the referenced letter.

This completes our work on the CAPA Feasibility Demonstration Program. We feel it was a very successful program, and we would like to thank all of the people at TARC who made such significant contributions to that success; including yourself, Captain Howell, Major Krull, Major Myser, and Sgt. Dolliver and many many more. We enjoyed working with you on the current CAPA program, and are looking forward to working with you on the next CAPA program.

If you need additional copies of the final report, or if we can be of service on some other matter, please do not hesitate to contact me.

Sincerely yours,

HONEYWELL INC.,
Aerospace Division

T.A. Whittaker

T. A. Whittaker
Program Administrator
Aerospace Support Equipment

TAW:kb
cc: Lt. Schisano/ASRFX

4 April 1969

ASE-690228

Department of the Air Force
Headquarters, Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio 45433

Attention: Capt. L. J. Schiano/53081-ASRFK

Subject: Final Report, Central Airborne Performance Analyzer (CAPA) Feasibility Demonstration Program

Reference: 1. Contract F33657-67-C-0743
2. Letter, dated 2-13-69, from R.P. Hickey to T.A. Whittaker

Gentlemen:

I am writing to transmit one (1) reproducible and four (4) copies of the subject report to satisfy the requirements of data item A010 of Exhibit A to the subject contract. The report has been prepared in accordance with Paragraphs 3.3.8., 3.6.5., 3.7., 3.8., and 6.4.10. of Contract Exhibit SEQ 66-9, and approved, by you, in the referenced letter.

This completes our work on the CAPA Feasibility Demonstration Program. It was a highly successful program, and we would like to thank all of the people at ASD who helped to make it so, including yourself, Mr. Minteer, Mr. Hickey, Mr. Wilgus, and particularily, Mr. Earl Lucius and Mr. Leo Gambone.

We are looking forward to working with all of you again.

Sincerely yours,
HONEYWELL INC.,
Aerospace Division

T. A. Whittaker
Program Administrator
Aerospace Support Equipment

TAW:kb
cc: Ed Burke - DCAS

CENTRAL AIRBORNE PERFORMANCE ANALYZER

J. E. Barker
W. L. Kruse
G. J. Mros

FOREWORD

This data item is the contractor's final report of the Central Airborne Performance Analyzer (CAPA) Feasibility Demonstration Program. It was prepared in accordance with paragraph 6.4.10 of Exhibit SEQ-66-9 to contract F33657-67-C-0743, and is submitted in accordance with Exhibit A to that contract as sequence number A010.

The program was sponsored by the United States Air Force, Air Force Systems Command, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, for the Tactical Air Reconnaissance Center, Tactical Air Command, Shaw Air Force Base, South Carolina, and was performed by Honeywell Inc., Aerospace Division, 2600 Ridgway Road, Minneapolis, Minnesota 55413. It was administered for the sponsoring agency by Mr. Leo Gambone, Project Engineer, Directorate of Reconnaissance Engineering, and by the following personnel for the requiring agency:

Mr. Thomas Julian, Program Manager

Major Larry D. Krull, Test Manager, Phase I

Captain Garvin T. Nowell, Test Manager, Phase II

Major Donald Myser, Test Officer, 4416th Test Squadron

This report presents an overall evaluation of the entire program from its inception in December 1966 to the conclusion of the feasibility demonstration flight tests in September 1968. It was assigned document number 20714-FR2 by the contractor. The manuscript was released by the authors in October 1968 for publication as a Technical Report.

This technical report has been reviewed, and is approved.

Leo A. Gambone

LEO A. GAMBONE
Checkout Equipment Branch
Analysis & Design Division
Directorate of Recon Engrg

Nathan R. Rosengarten

NATHAN R. ROSENGARTEN
Technical Director
Reconnaissance Engineering

ABSTRACT

Studies have shown that significant improvements in aircraft effectiveness (availability, mission success, spares, aerospace ground equipment requirements) will result if system monitoring and fault isolation can be done in-flight during actual operation of those avionics systems which have the lowest reliabilities. The Central Airborne Performance Analyzer (CAPA) was used in this program to demonstrate the feasibility of in-flight fault isolation. The CAPA was installed in an RF4C aircraft and interfaced with the electronics systems of the side-looking radar, infrared detecting set, and KS72 camera without altering the circuitry of these systems. Data gathering missions were flown to acquire information about the signals being monitored. The CAPA was then programmed to continuously monitor the aircraft systems, detect any malfunction, isolate the malfunction to a line replaceable unit (LRU), and print the location of the malfunction along with the time of occurrence. In short, the CAPA produces an easily understood maintenance message which is available to the flight line crew immediately upon aircraft landing, without the use of flight line aerospace ground equipment or any ground data processing. Data developed during the test program proved the technical feasibility and showed that the application of CAPA to RF4C reconnaissance systems would increase the aircraft's effectiveness by 30 percent through increased aircraft availability and a greater number of successful missions.

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SECTION I

INTRODUCTION

This report presents the results of a program that demonstrated the technical feasibility, operational benefits, and economic worth of applying the in-flight Central Airborne Performance Analyzer (CAPA) to the reconnaissance sensors of the RF4C aircraft.

Problems with identification and isolation of malfunctioning portions of the sensors used on tactical reconnaissance aircraft are unique because, unlike most other systems, there is often no immediate, direct evidence of a failure until films are processed -- an operation that takes place 2 to 6 hours after the films have been exposed. The reconnaissance sensors make use of physical characteristics that do not lend themselves to testing in the ground or static environments, thus built-in-test equipment (BITE) and ground test equipments are ineffective. The delay in malfunction recognition from these causes significantly reduces the effectiveness of the RF4C.

The CAPA provides a central system which continuously monitors and analyzes the performance of selected aircraft systems without modifications to them. It is the function of the CAPA to produce maintenance messages in flight that indicate which system is malperforming and specifically which line replaceable unit (LRU) should be replaced to effect repair.

The objectives of the program were:

1) Demonstrate technical feasibility.

2) Demonstrate practical feasibility by showing that the approach is suitable for retrofit on existing aircraft and that it causes no degradation in the performance of the systems under test.

3) Demonstrate the value to the Air Force by performing the maintenance evaluation in the operational environment and by generating usable maintenance messages.

SECTION II

CAPA IN-FLIGHT TEST CONCEPT

In-flight testing is unlike most other testing in that:

1) The systems being tested continue their functions without interruption while being tested.

2) The systems being tested are tested in their normal environment under operating conditions.

3) The systems being tested are evaluated continuously throughout the flight.

4) Test results can be made available directly during flight so that valid decisions can be made to maximize the payoff of the mission.

With these differences evident, it is to be expected that the basic philosophy used in in-flight testing differs from that of classical ground testing. In dynamic systems, signal levels can vary over a wide range during normal performance. It is thus necessary to judge the state of "goodness" of an in-flight dynamic system by the relationships between two or more signals rather than on the value of one signal. In essence, one must go back to the fundamental purpose of the system or subsystem being tested, and determine in specific engineering terms its intended function and acceptable range of performance. Under certain situations, such as in a servo follower at null, "normal" signal levels are below the established threshold. In this case, the analyzer must determine if the measurement represents a "normal" condition or defer the test decision until signal levels are high enough to allow an accurate assessment of performance.

After a major function of a system is found to be malperforming, the in-flight analysis equipment must isolate the malfunction to a given LRU. This step is necessary because the component elements that together perform a given function may be physically housed in three or four different LRUs. To accomplish this fault isolation, each major function is divided into separately identifiable subfunctions which lie within a single LRU. When the location of the fault has been isolated to the LRU, the appropriate identification is printed.

SECTION III
PROGRAM HISTORY

The CAPA program started in the early part of December 1966. It consisted of two phases. Phase I was an application analysis culminating in a compatibility and data gathering flight test. Phase II was the actual demonstration of in-flight fault isolation.

Initial efforts were directed toward analyzing the aircraft subsystems to be monitored and selecting test points from those subsystems which promised to yield the most meaningful data for in-flight fault isolation. The analysis produced a list of aircraft test points and the type of isolation proposed for each test point. The original list contained 111 test points for side-looking radar (SLR) testing, 58 test points for infrared (IR) detection set testing, and 4 for the KS72 still-picture camera. The CAPA was then programmed for gathering flight data on these test points. A compatibility-integration test was conducted during September 1967 using the CAPA and bench-connected sensors. This test verified that the aircraft subsystems experienced no degradation in performance because of the interface with the CAPA.

The Phase I aircraft installation and data gathering flight tests were conducted during September 1967. The CAPA was installed in RF4C, Serial No. 832, assigned to the 4416th Test Squadron, Shaw AFB, South Carolina. Six sorties were flown which produced a total of 229 minutes of CAPA operating flight time.

The CAPA was returned to Minneapolis for Phase II programming of the in-flight tests based on the data obtained during the data gathering flights. The unit was reinstalled in the aircraft at Shaw AFB in February 1968. Six verification flights were made to ensure that the program was operational, and demonstration test flights were started in March 1968. Thirty sorties were flown, providing the CAPA with over 33 hours of operational airborne time. The test program terminated in September 1968.

SECTION IV
TEST RESULTS

FEASIBILITY

The ability to produce accurate, printed maintenance messages in flight was successfully demonstrated. Producing the correct message in 80 percent of the cases was established as the criterion for complete success of the program. The average score for the test flight program was 91.9 percent. The 80-percent goal was attained or surpassed in 29 of the 30 flights.

The analysis contained 17 malfunctions which required hardware repair; these included replacement or adjustment of LRU components. Also included in the analysis were 24 malfunctions which did not require hardware repair on the LRUs being tested; these included film runouts, incorrect input conditions from other avionics systems, and other similar conditions which affect the quality of the imagery. Five additional conditions, including a disconnected cable and simulated malfunctions using the BIT (built-in test) switch, were also included in the analysis. A complete list of these items appears in Appendix V.

The test plan called for operation of the aircraft and the maintenance procedures to continue as if the CAPA did not exist. The printed CAPA maintenance messages were then compared with the actual maintenance actions and sensor performance. The messages included the LRU designation, LRU status, and the time of occurrence, which allowed close correlation with the pilot reports and sensor imagery.

The data from the demonstration flight test shows that if the CAPA had been used as the basis for maintenance actions, 47.3 percent of the sensor flight line maintenance hours would have been saved due to the reduction of false removals and the reduction of diagnostic time. In addition, 14.6 percent of the total bench repair time would have been saved as a result of the reduction of false removals.

TEST LIMITATIONS

Although the program demonstrated the technical and practical feasibility of the CAPA, the test program was not long enough to produce enough statistical data which could independently determine the extent to which CAPA could increase flight line maintenance effectiveness and reduce turnaround time, and spare parts inventory required for normal operation of the RF4C. However, there is excellent correlation between the CAPA experience and AFM 66-1 data. The experienced mean-time-between-failure (MTBF) for the side-looking radar was 2.55 hours, which compares with 2.8 hours based on AFM 66-1 factored to reflect actual operating hours rather than flight hours. The available information was used by Operations Analysis along with AFM 66-1 data to predict in greater detail the effect of the CAPA on reconnaissance operations.

SECTION V
OPERATIONAL BENEFITS

A mathematical analysis of operational benefits and economic benefits associated with a CAPA test system was conducted to obtain measures of effectiveness and implementation and maintenance costs. The effectiveness analysis was performed to evaluate operational improvements possible through the use of a CAPA test system. The economic analysis was performed to yield a figure of total system merit.

METHOD

The test system impact on the logistics and maintenance requirements of a wing of 60 RF4C aircraft was analyzed through the use of a mathematical model entitled PLANET. PLANET (Planned Analysis and Evaluation Technique) was developed for the Air Force by the RAND Corporation under DOD directive 4100.35. It is a large model of the complex maintenance and logistics actions and interactions which take place on a typical Air Force Base. The analysis was approached with two primary comparisons as the end objective. They were:

1) A comparison of model results versus actual RF4C AFM 66-1 data

2) A comparison of the effectiveness of a wing of RF4C aircraft with and without the CAPA test system

The first comparison was used as an indication of the model validity. The second comparison was made to obtain a measure of the logistics and maintenance improvement factors due to use of the CAPA. The details of the model and the study methods used are discussed in detail in Appendix VI.

ANALYSIS RESULTS

The model outputs in terms of maintenance manhours, failures, and failure rates correlate closely with actual Air Force RF4C experience as reported in the AFM 66-1 data system. MTBF times from the model agree within a 78-percent correlation factor with those reported in AFM 66-1.

The effect of the CAPA (monitoring six systems) is a 22.8-percent increase in the effectiveness of the reconnaissance system maintenance manpower at the flight line (Figure 1). The CAPA reduces the skill level requirements for flight line diagnosis of system troubles, making a maintenance technician effective at the flight line earlier in his training cycle (Figure 2). Analysis indicates that existing spare levels are adequate for flight line maintenance if the CAPA is used (Figure 3). Flight line test equipment requirements are reduced by as much as 83 percent.

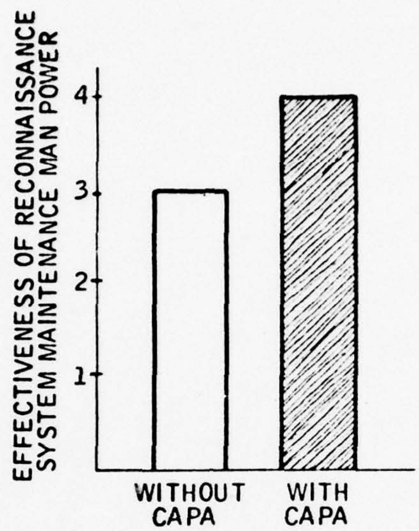

Figure 1. Manpower Effectiveness

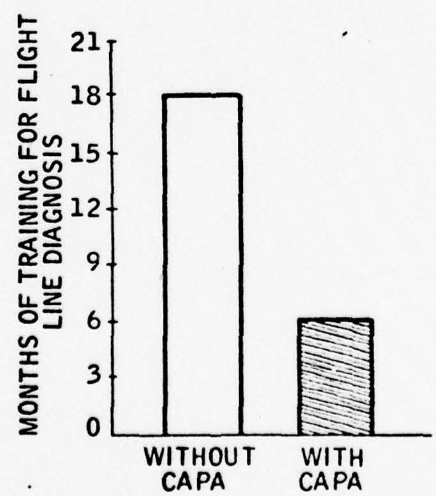

Figure 2. Training Requirements

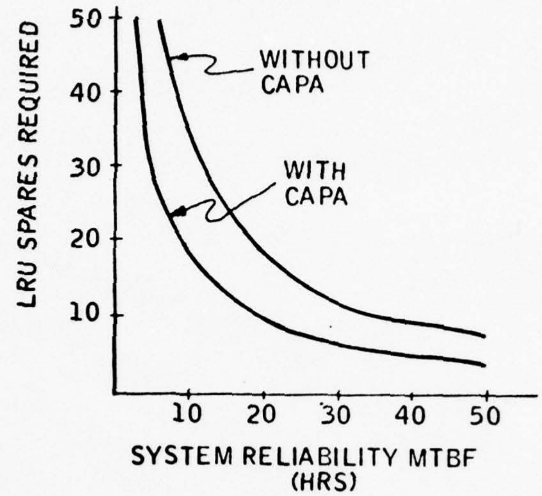

Figure 3. LRU Spares Requirements

Improved availability and improved mission success contribute to a 30-percent improvement in operational effectiveness (Figure 4). Average turn-around time decreases from 11.1 hours without the CAPA to 9.1 hours with the CAPA. Cost analysis shows that these benefits are the equivalent of $277,000 per year per aircraft.

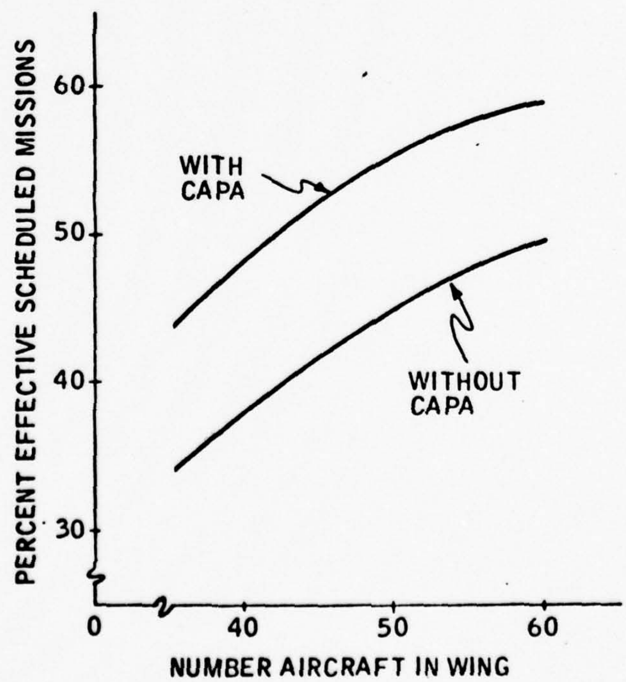

Figure 4. Operational Effectiveness

SECTION VI
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1) The prime objectives of the CAPA program were achieved. These objectives were:

   - Prove the feasibility of in-flight system failure detection and isolation.

   - Obtain printed maintenance messages which isolate malfunctions to the correct LRU in greater than 80 percent of the malfunctions that occur.

   - Interface off-the-shelf test hardware with the reconnaissance sensors without causing degradation to the systems involved.

2) The variety of signals monitored and tested in the side-looking radar, infrared detecting set, and still-picture camera systems establishes that the CAPA system can be expanded to include any airborne system.

3) The in-flight test concept is capable of determining the mode of operation for a reconnaissance system and adjusting the test process or test limits of system performance under actual operating conditions.

4) An operational CAPA system would increase the effectiveness of flight line maintenance manpower by 22.8 percent and reduce flight line test equipment by 83 percent, while increasing operational effectiveness by 30 percent.

5) The results of this program indicate that the CAPA meets the intent and purpose of TAC's Aircraft Integrated Data System as outlined in ROC No. TAC-43-67, dated 30 June 1967.

RECOMMENDATIONS

1) Expand the CAPA application to additional aircraft systems selected on the basis of their contribution to the maintenance problem and their significance to the reconnaissance mission.

2) Revise output message format to produce a direct English language maintenance message.

3) Repackage CAPA hardware to meet military specifications for airborne electronic equipment and to facilitate permanent installation in RF4C aircraft.

4) Apply the capability of the CAPA to preflight ground testing.

5) Prove operational suitability of the revised application and hardware configuration.

APPENDIX I
EQUIPMENT DESCRIPTION

INTRODUCTION

The Central Airborne Performance Analyzer (CAPA) consists of a central processor, two remote units, an optional magnetic tape recorder, a printer, and a control panel. The central processor contains the measurement and arithmetic circuitry, as well as the memory which directs the program and causes the correct decisions to be made. The remote units contain the switches, signal isolation circuitry, and buffer amplifiers necessary to select and condition the signals from test points in the various aircraft subsystems being monitored. The magnetic tape recorder is used to record signals for possible post-flight analysis. It is intended primarily as an engineering tool during flight test. The printer prints messages in-flight concerning the status of the subsystems and LRUs being monitored. The control panel is used to turn the CAPA on and off.

The RF4C subsystems monitored by the CAPA are the AN/APQ-102 Side-Looking Radar, the AN/AAS-18 Infrared Detecting Set, and the KS72 Camera.

During normal operation of the CAPA, the memory section of the central processor determines which test should be executed. The information necessary to select the correct test points is then sent to the remote units and multiplexing circuitry of the central processor. Signals from the selected test points are buffered in the remote units, and then sent to the central processor where they are measured and analyzed. The data is recorded on magnetic tape for reference. If the analysis shows the data to be normal, the in-flight program is signaled that the test was good, and the next test is initiated. If the analysis shows the data to be abnormal, the fault is isolated to a line replaceable unit (LRU) and the printer is directed to print the identity of the failed LRU. The test sequence then proceeds to the next logical test, depending on the failure encountered and subsystem operating modes selected.

CAPA SYSTEM CONFIGURATION

The YG1019A CAPA system (Figure 5) for the RF4C aircraft consists of the following units:

- Right Remote Unit, UG2186A
- Left Remote Unit, UG2187A
- Central Processor, UG2184A

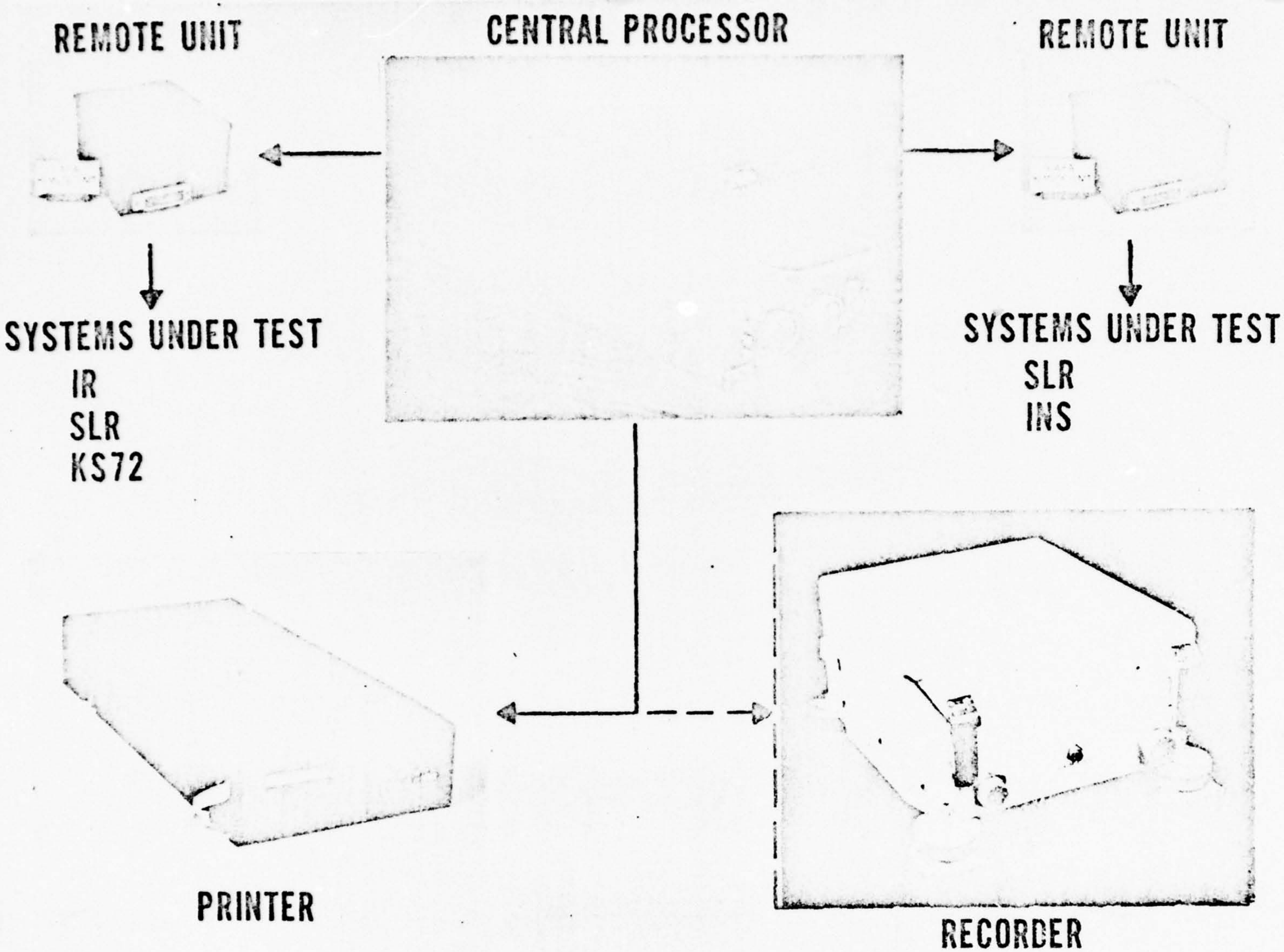

Figure 5. YG1019A CAPA Test System

- Printer, UG2227A
- Recorder, UG178A
- Control Panel, UG2228A

Each of these units is discussed below.

Remote Units

Each remote unit (Figure 6) contains test point addressing circuitry, test point selection switches, high-input impedance buffer amplifiers, and isolation or protection circuitry to prevent CAPA degradation of the aircraft system signals. A block diagram of the remote unit is shown in Figure 7. There are up to 128 test point switches per remote unit, with only seven interconnecting wires between each remote unit and the central processor.

Central Processor

The central processor (Figure 8) contains the multiplex switching for selecting the remote units to be examined, and the necessary circuitry for transmitting command signals to the remote units for selecting the desired test points. A block diagram of the central processor is shown in Figure 9. Two channels of track and hold circuitry provide the capability of a single or simultaneous measurement of one or two selected signals, respectively, from the same remote unit, or similar measurements on two selected signals consisting of one from each of two remote units. The track and hold channels, under program control, can hold (sample) the selected signals both asynchronously (at any instant in time) and synchronously (relative to the peak of the aircraft 115-volt ac, 400-Hz, phase-C signal).

Also under program control, one of the track and hold outputs (sampled signals) is fed to the decision amplifier/ratio digitizer network in the measurement section which performs high-speed voltage or voltage ratio measurements (analog-to-digital conversions). The measurement section also contains a counter, a precision clock, and a number of time reference signals which enable frequency, period, and time period-type measurements to be made. The arithmetic section can perform computations and logic operations specifically tailored to test applications. The central processor has a six-word scratch pad (13 bits per word) memory and a 2048-word (18 bits per word) random-access program memory. The central processor provides output commands to the printer and recorder.

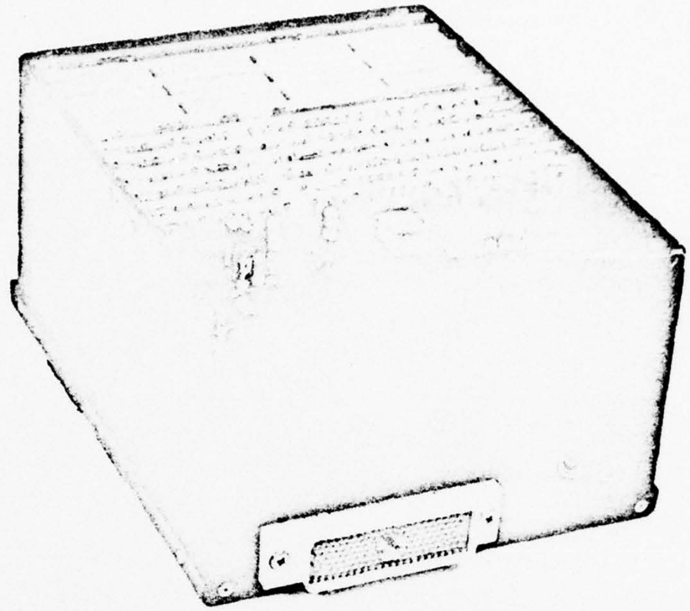

Figure 6. CAPA Remote Unit

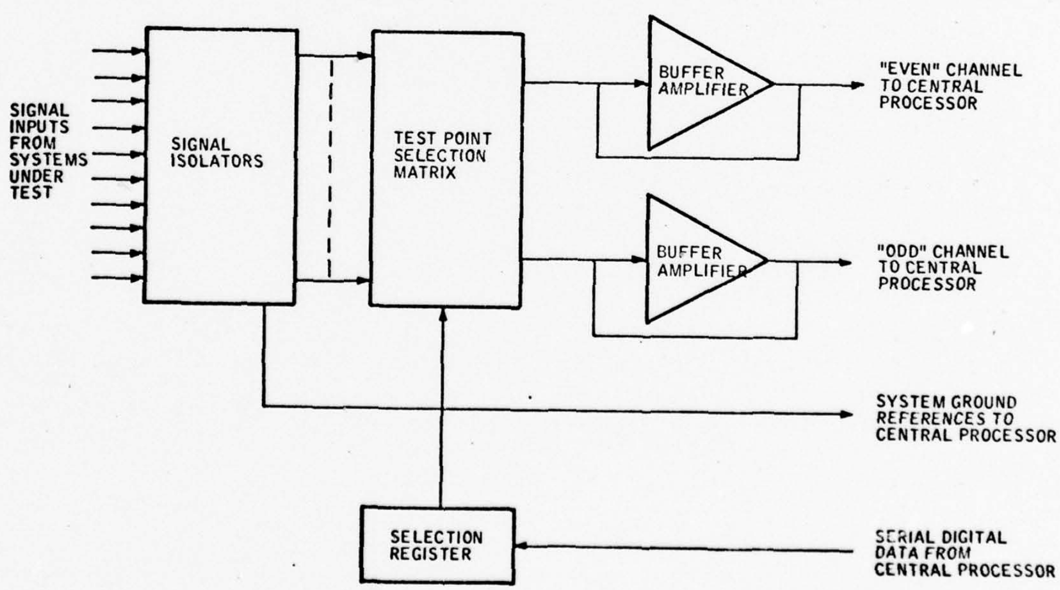

Figure 7. Remote Unit Block Diagram

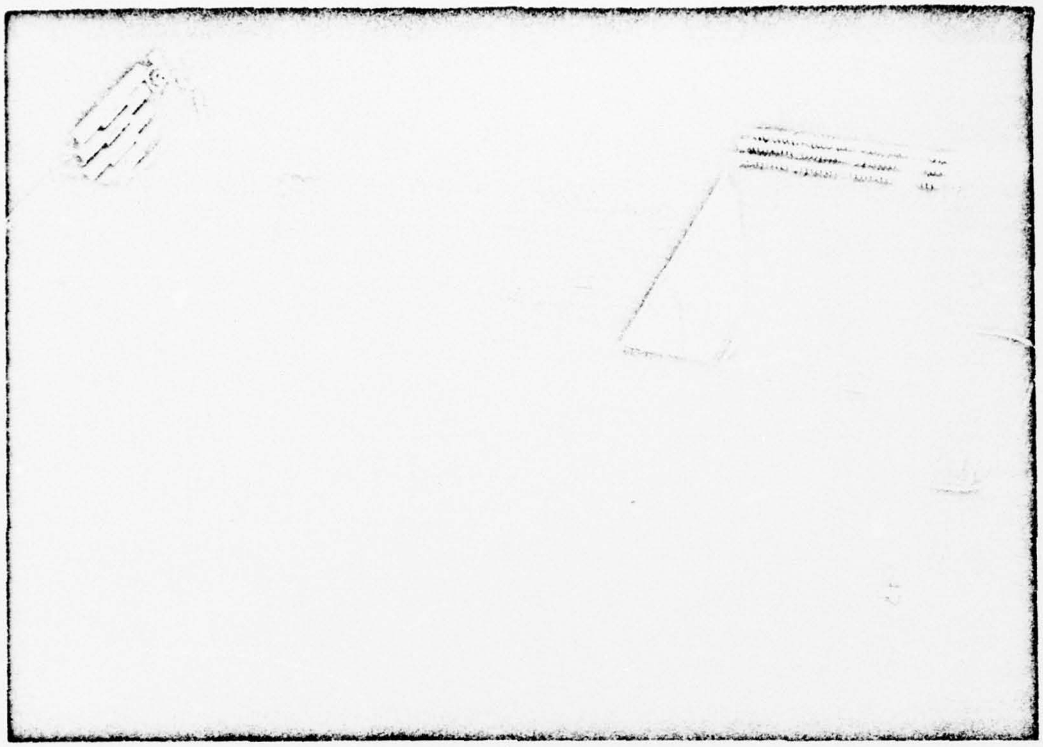

Figure 8. CAPA Central Processor

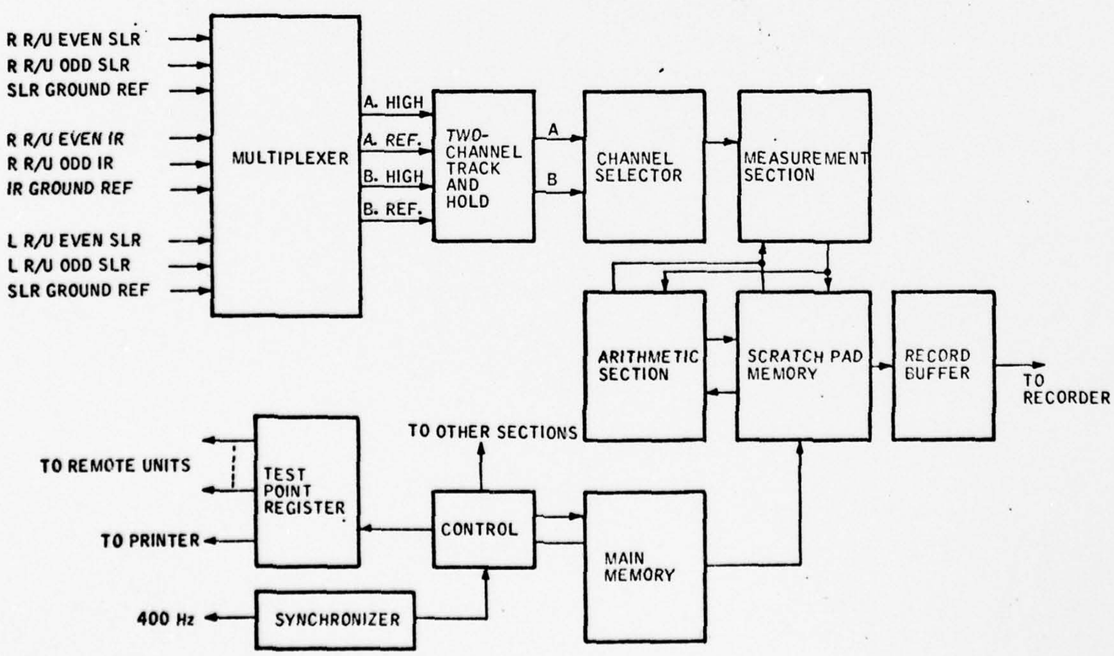

Figure 9. Central Processor Block Diagram

Printer

The printer (Figure 10) is a lightweight, subminiature, single-column tape character printer with a printing capability of 64 letters, figures, and symbols. A six-level parallel intelligence incoming signal is converted into mechanical motion to position the print cylinder. Upon receipt of the print command, the selected character is printed on pressure-sensitive tape. Immediately after printing, the tape is advanced one space for the next character.

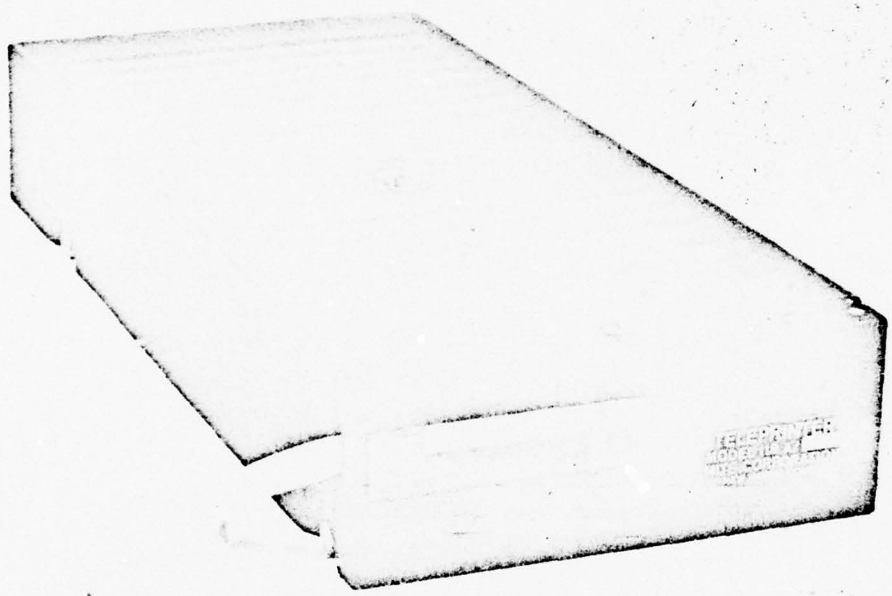

Figure 10. CAPA Printer

Recorder

The recorder (Figure 11) provides storage of digital data developed by the digitizer or computational circuits of the central processor. It records the 12 most significant bits of a data word in two frames of data. The recording medium consists of 1800 feet of 1/2-inch tape -- a length sufficient for two hours of data recording at a rate of 500 conversions (12-bit words) per second in a format compatible with general-purpose ground computers.

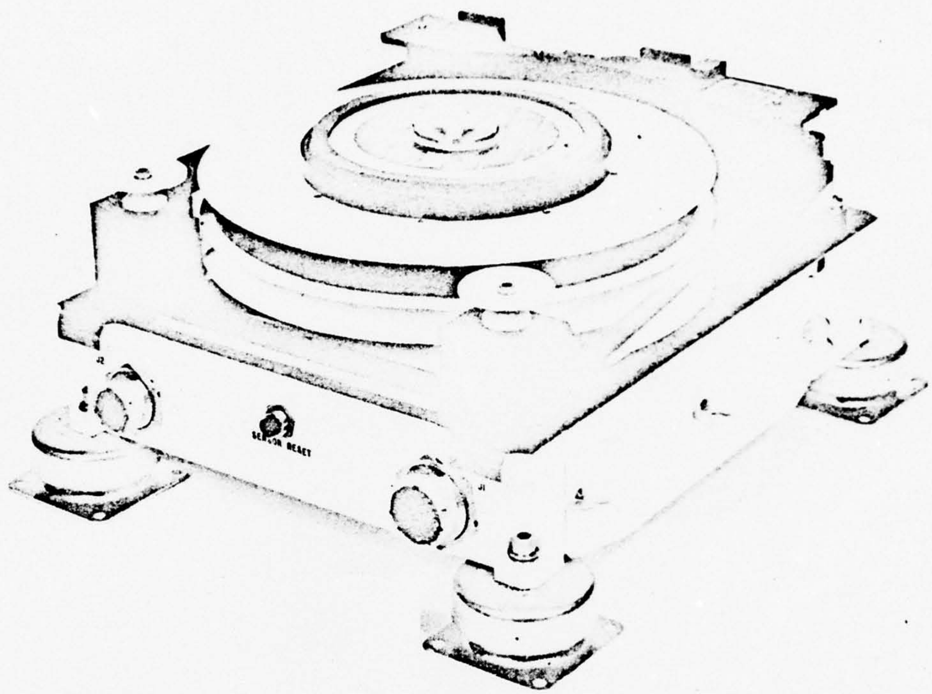

Figure 11. CAPA Recorder

Control Panel

The control panel consists of a single on-off switch in the cockpit. This switch controls all the power to the CAPA test system.

APPENDIX II

IN-FLIGHT TEST SOFTWARE

TEST PHILOSOPHY

Since the Central Airborne Performance Analyzer (CAPA) operates in a dynamic environment, it is essential to ensure that test conditions are valid for each test before the test is executed. To accomplish this, tests within each system test routine are arranged in a sequence of increasing dependence on the previous tests. This ensures that all conditions and operating modes required for a specific signal are correct before that signal is tested. Before a line replaceable unit (LRU) is flagged NO-GO, a failure within that LRU must be detected and then retested to confirm the failure.

TEST ORDER

The CAPA in-flight test program is divided into four system test routines: (1) the CAPA system self-test routine; (2) the camera system test routine which checks the KS-72A still-picture camera, (3) the SLR system test routine which checks the AN/APQ-102 side-looking radar set; and (4) the IR system test routine which checks the AN/AAS-18 infrared reconnaissance detecting set. The SLR and IR system test routines include testing the signals supplied to the three reconnaissance systems by the inertial navigation system (INS), camera control, and aircraft power supply systems.

The systems are normally tested in the following order: (1) CAPA self-tests, (2) camera system, (3) SLR system, and (4) IR system. Each system is checked repeatedly unless a malfunction is encountered within that system, in which case the system continues to be checked repeatedly up to the point in the test sequence where the malfunction is detected. When the malfunction disappears, the complete system test is resumed.

MAINTENANCE MESSAGES

The CAPA single-column printer produces a seven-character message for each change in system status. Each message consists of an arrow, which points upward for a "GO" message and to the left for a "NO-GO" message, followed by four digits giving the time since turn-on in minutes and tenths of a minute, and a system LRU code consisting of one of the following:

SN: SLR navigation inputs

SI: SLR input conditions

SR: SLR ready status

S1: SLR LRU 1, SLR recorder control LRU
S2: SLR LRU 2, SLR recorder LRU
S3: SLR LRU 3, SLR amplifier modulator LRU
S4: SLR LRU 4, SLR right antenna control LRU
S5: SLR LRU 5, SLR frequency converter transformer LRU
S6: SLR LRU 6, SLR reference computer LRU
S7: SLR LRU 7, left antenna control LRU
CK: KS72 camera ready condition
CF: KS72 camera fail indicator
CI: IR input power
CR: IR ready condition
C1: IR LRU 1, power supply LRU
C2: IR LRU 2, IR recorder LRU
C3: IR LRU 3, IR receiver LRU
C4: IR LRU 4, IR film magazine
C5: CAPA central processor
C6: CAPA right remote unit
C7: CAPA left remote unit

The message "@@←0000C5 ↑0000C5" is printed each time the CAPA is turned on as the self-test is executed.

A sample CAPA printing sequence might be as follows:

@@	- Clock initialization symbol
←0000C5	- CAPA self-test-induced failure
↑0000C5	- CAPA-induced failure removed
←0000CK	- Camera initially off
←0000SR	- SLR initially off
←0000CR	- IR initially off
↑0051SR	- SLR on at 5.1 minutes elapsed time
←0053S3	- SLR amplifier modulator failure at 5.3 minutes elapsed time

The interpretation of this sample printing sequence would be as follows: When the CAPA is turned on, the clock is set to zero and "@@" is printed to indicate the initialization. An incorrect self-test decision is applied to the CAPA central processor and then removed to see if the CAPA will correctly print central processor NO-GO: "←0000C5" and then central processor GO: "↑0000C5". After the CAPA self-test, the status of the other systems is printed. Normally, the camera, SLR, and IR are still off when the CAPA is turned on, so the CAPA prints that the camera ready signal is NO-GO at time zero "←0000CK", the SLR ready signal is NO-GO at time zero "←0000SR", and the IR ready signal is NO-GO at time zero "←0000CR". After 5.1 minutes, the SLR is turned on, so the CAPA prints that the SLR ready signal is GO at 5.1 minutes of elasped time: "↑0051SR". However, the SLR amplifier modulator fails shortly after the SLR is turned on. This results in the CAPA printing that the amplifier modulator LRU is NO-GO at 5.3 minutes of elapsed time: "←0053S3".

PROGRAM STRUCTURE

The CAPA random-access program memory contains test limits, test routines, and the main sequence program for controlling the entire analyzer system. The basic steps required in any test are:

1) Select proper test points
2) Make measurement
3) Compute performance
4) Compare performance with allowed range
5) Branch to next test (as determined by previous step)

Since there are only several basic types of tests, they are stored as common test subroutines. To perform a specific test, the CAPA selects the proper test points, supplies performance limits, and then transfers control to the appropriate measurement subroutine. When this subroutine is completed, the appropriate message is printed, if necessary, and control is transferred back to the main routine for continuation to the next test.

If a malfunction is discovered, the test sequence starts again at the beginning of the system routine in which the malfunction was found. Since test point selection and testing are arranged in an increasingly dependent order, the first test point which indicates a malfunction during the repeat cycle is considered to be the origin of the malfunction, and the CAPA prints the LRU in which this failure exists. The CAPA self-test requirements are more stringent and if a self-test failure occurs, testing of all other systems is suspended until CAPA operation returns to normal, effectively filtering out transient difficulties. This ensures that an aircraft system malfunction is not erroneously indicated as a result of abnormal CAPA operation.

After the failure location is printed, the remainder of the system routine in which the failure was found is omitted and the next system routine is started. Each system is checked once during each cycle of the in-flight program. If a failure was previously found and indicated, the system containing the indicated failure is checked to see if the failure still exists. The printer does not produce a message for a given LRU failure each time it is encountered on successive tests, but rather only prints on changes of state. In the event that a malfunction is intermittent during the flight, the CAPA system indicates when the failure appears or disappears. Complete testing of the system is then resumed. The CAPA in-flight program consists of the following sections:

- System Test Routines -- A separate system test routine exists for the SLR, IR, KS72 camera, and the CAPA self-test. These routines determine the sequence of test point selections, the types of measurements and arithmetic calculations required for each decision, and the required standard values (limits) for each test.
- Standard Value Subroutine Table -- This table contains the necessary standard values for all tests.
- Measurement Subroutines -- These sections perform the actual a-c, d-c, ratio and frequency measurements.
- Limit Subroutine -- This section determines if a measurement or calculation number result constitutes a GO or NO-GO condition and records the data used in the decision.
- Status Subroutine -- This subroutine monitors the operating modes and status of all sensor LRUs.
- Print Subroutine -- This section directs the CAPA printer to print the appropriate message when the status subroutine encounters a change of status of a sensor LRU or operating mode.
- Auxiliary Subroutines -- These subroutines perform special functions or arithmetic calculations necessary for program operation.

The program steps required to perform a test to determine whether a GO or NO-GO condition exists is illustrated by the simplified block diagram of program flow shown in Figure 12. The system test routines ensure that the correct remote unit, test point, channel, and test measuring subroutine is selected for a specific test. Program control is then transferred to the Standard Value Table which selects the limits (upper and lower bounds) for the measurement. The testfinder subroutine then branches to the appropriate test. The measurement result is compared with the previously selected limits by the limit subroutine to determine whether a GO

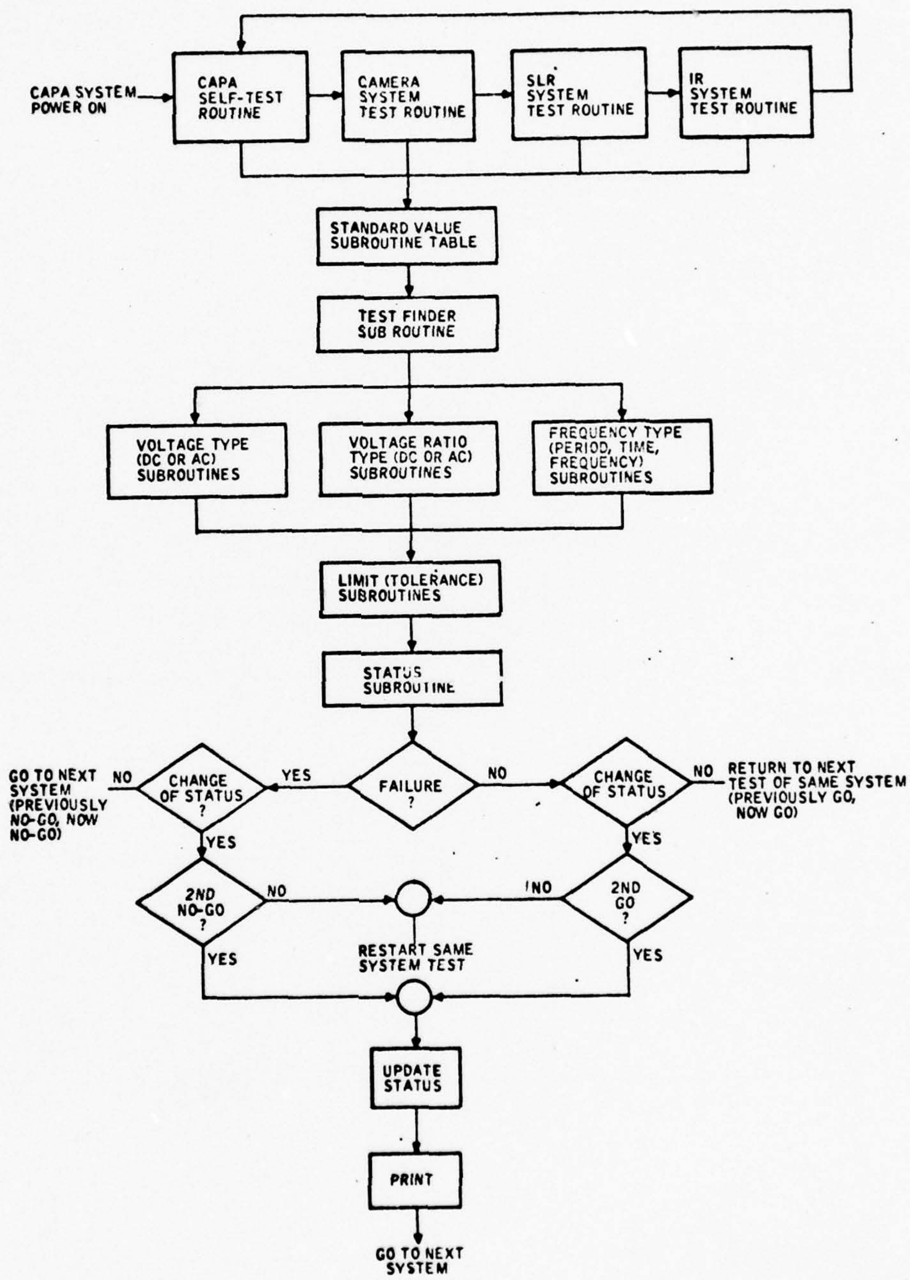

Figure 12. Program Flow Block Diagram

or NO-GO condition was encountered. If an LRU or operating mode has changed status, the status subroutine updates the old status and exits to the print subroutine. Otherwise, the status routine returns control to the test routine of the system being tested in preparation for the next test. The print subroutine, after printing the status change, exits to the next system test routine.

TEST EXECUTION PROCEDURE

One of several types of measurements is performed on each aircraft system test point. The characteristic of the test point signal determines which measurement type is initiated. The following sequence of events is necessary to connect the aircraft system signal under test to the central processor measurement section (reference the central processor block diagram, Figure 9).

1) Select Test Point -- The appropriate signal is selected by operating an input selection switch in the remote unit with a Select Test Point instruction command. Each selection switch enables two signals to be transmitted to the central processor; one signal on the remote unit even channel and the other on the remote unit odd channel.

2) Select Remote Unit -- The multiplexer network in the central processor connects the appropriate remote unit channel to either track and hold channel A or B. The Select Remote Unit instruction command controls the multiplexer selection.

3) Select Channel -- The channel selector then connects the appropriate track and hold channel to the measurement section. The Select Channel instruction command controls the channel selection.

The track and hold channels, when in the track mode, continuously track the selected aircraft system test point signals. The signal of interest is now available to the measurement section for one of the following measurements:

- Voltage Measurements (dc or ac) -- An asynchronous or synchronous sample (hold) is initiated for a d-c or a-c voltage measurement, respectively. The "held" voltage is then applied to the decision amplifier/ratio digitizer network for an analog (voltage)-to-digital (A/D) conversion according to the expression:

$$V = \frac{V\,(\text{held})\; 4.096}{\text{RADACON}} \quad \text{volts}$$

where RADACON stands for ratio analog-to-digital converter.

Since the RADACON normally equals 4.096 volts, the conversion result equals the unknown held voltage. Both track and hold amplifiers are held simultaneously when a hold command is initiated. Therefore, a voltage ratio measurement can be accomplished by two successive A/D conversions. After the first A/D conversion, the result is transferred to RADACON. The second A/D conversion (other track and hold channel) equals the ratio of the two voltages multiplied by the A/D-converted full-scale output (4.096 volts) according to the expression:

$$V = \frac{V_2 (4.096)}{V_1} \text{ volts}$$

The two voltages are selected in a manner which ensures that the ratio is nominally less than 1 to guarantee the voltage ratio measurement is within the bounds of the A/D converter (-4.096 to +4.096 volts), thus eliminating A/D converter saturation (overflow).

- Period and Time Period Measurements -- These measurements increment the measurement section counter at a 1-MHz rate (1 count every 10^{-6} sec). The counter begins incrementing when the signal crosses the selected threshold in the positive direction and terminates at the next selected threshold crossing in the positive direction. The selected threshold is equal to the voltage represented by the digital contents of the arithmetic register (accumulator) when the measurement is initiated. After the time period measurement begins, an automatic channel select is performed to select the signal on the other track and hold channel which determines when the measurement is terminated. The period measurement is identical to the time period measurement except that the automatic channel select is not executed. In this instance, the same signal is used to initiate and terminate the measurement counter. These measurements represent the time between two events or the period of a cycle (time/cycle).

- Frequency Measurement -- This measurement is similar to the period measurement except that the counting function is mechanized differently. A time aperture (504 microseconds to 3.67 seconds range) is selected when the measurement is initiated. The measurement counter then advances by one count, each time the signal crosses the selected threshold in the positive direction. An additional counter is used to terminate the measurements when the measurement elapsed time equals the preselected aperture. The threshold is determined by the digital contents of the arithmetic register. This measurement represents the number of cycles of the signal during a specific time or the "frequency" of the signal (cycles/time).

The results of each of the above measurements appear in digital form in the first location of the scratch pad memory, and the record buffer circuitry, under program control, records these results on the 1/2-inch magnetic tape of the recorder units.

TEST RATE

The complete test program contains 173 separate tests distributed as follows:

System	Tests
CAPA self-check	10
KS72 camera	2
SLR	112
IR	49
Total	173

A test may contain more than one measurement; however, it produces only one GO or NO-GO decision. The time required to complete the entire program depends on the system configuration and mode of operation During normal operation, the time required for the complete cycle is approximately 4 seconds.

APPENDIX III
CAPA-AIRCRAFT INTERFACE

The interface between the Central Airborne Performance Analyzer (CAPA) and the aircraft subsystems consists of connections to aircraft test points for signal monitoring and connections to the camera circuit breaker panel for 28-vdc and 115-vac power. The power inputs are the only instances where connections are made to the aircraft wiring. Signals are monitored by mating with existing test connectors on the aircraft or subsystem line replaceable units (LRUs). A block diagram of the interfaces is shown in Figure 13.

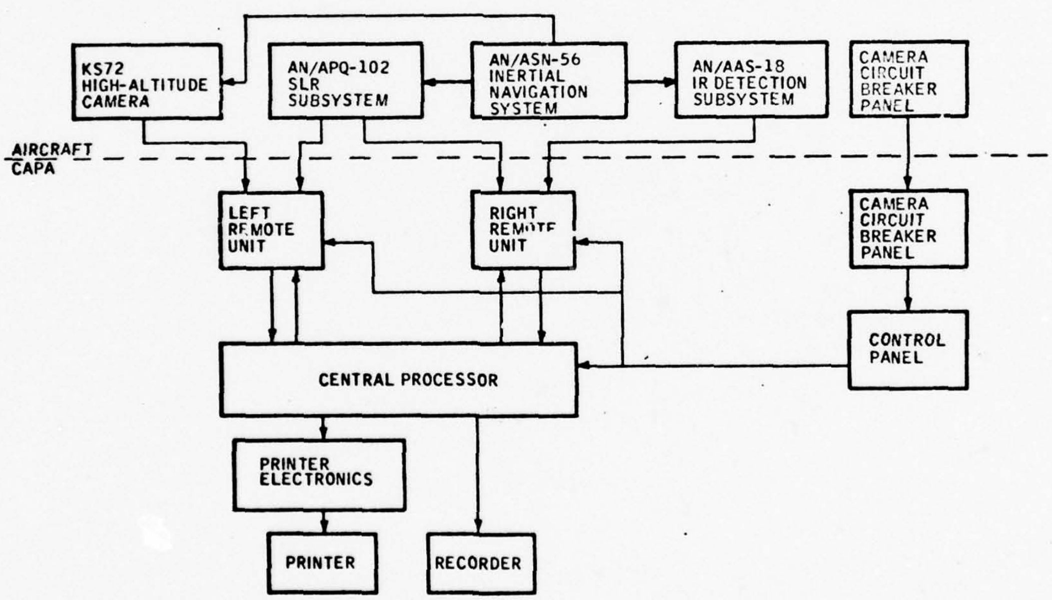

Figure 13. CAPA/Aircraft System Interface

The CAPA monitors signals from existing sensor test points, and necessary signal isolating and conditioning is contained in the remote units. The functions of the signal conditioning are:

1) Isolating -- A high-impedance circuit is connected between the aircraft test point and the CAPA selection matrix for each test point to avoid loading the test signal and to prevent accidental shorting.

2) Converting -- This consists of detecting certain signals, such as video and other high-frequency signals, and stretching short pulses to make them more recognizable to the measurement section.

3) Combining -- In cases where a deviation in any one of several signals indicates the same abnormal condition, the test signals are combined to produce a single output to the measurement circuitry.

The CAPA monitors 179 of 228 available test points. Some of the unused test points pertain only to aerospace ground equipment and bench test equipment and are not applicable to in-flight testing.

APPENDIX IV
CAPA PROGRAMMABLE INSTRUCTIONS

HALT

Mnemonic: HLT

Command Code: 00_8

The HLT command prevents the advance of the sequence counter; therefore, the sequence counter state (SC) will correspond to the program memory location (L) containing the HLT command.

The HLT command is active only when the control and display unit is connected to the processor. When the control and display unit is not connected to the processor, the sequence counter will advance to the next command as though the HLT was a no-operation command.

SELECT TEST POINT

Mnemonic: STP

Command Code: 01_8

The STP command operates pairs of signal input selection switches in a specified remote unit to connect pairs of input connector pins (n and n+1) to output lines E_N and O_N. The even-numbered pins, $n = 0, 2, 4, 6 \ldots\ldots$, are selectively connected to the E_N output line, and the odd numbered pins, $n + 1 = 1, 3, 5, 7 \ldots\ldots$, are selectively connected to the O_N output line.

The STP command requires one program cycle for its initiation; however, the circuits which serialize the selection digits are busy for another six cycles, or for a total of 196 microseconds. This means that STP commands can be issued no more frequently than one out of seven program steps. Consequently, when a number of selections are to be made in the shortest time span, and when each selection involves a different remote unit, a waiting period of 168 microseconds can be programmed. This is done by addressing an STP circuit busy signal with the Skip If Signal Set (SKS) command, followed by a Jump (MMP) to SKS.

When a switch selection is to be followed as soon as possible by a measurement, the program must "wait" for the selected relay to stabilize (1.5 milliseconds). This is done by addressing a relay engage signal, with the SKS and JMP to SKS commands.

SELECT REMOTE UNIT

Mnemonic: SRU

Command Code: 02_8

The SRU command addresses a high-speed analog multiplexer which connects either one of two signal lines (E_n or O_n) from a specified remote unit to the track and hold amplifier channel A and the other signal line to the track and hold amplifier channel B. The multiplexer may also connect one signal line from each of two remote units to the track and hold channels. When either E_n or O_n is connected to a track and hold channel, a signal reference line is also connected to the appropriate channel.

The track and hold channels may operate with a common mode voltage with respect to logic ground of 4.0 volts; however, the instantaneous sum of the signal and common mode voltages should not exceed 4.095 volts.

SKIP IF SIGNAL SET

Mnemonic: SKS

Command Code: 03_8

The SKS command addresses specific measurement instrumentation, arithmetic logical functions, and control unit SKS switches; it then determines whether the addressed function is in the state 0 or 1. If the state of the addressed function is 1, the command at L + 1 is inhibited, and the SC will simply advance from L + 1 to L + 2.

The SKS command is capable of addressing more than one function at a time, and either function would cause step L + 1 to be inhibited. This allows simulation of certain real-time events through the use of the control unit switches during program checks or during processor instrumentation checks.

MARK PLACE AND BRANCH

Mnemonic: MPB

Command Code: 04_8

The MPB commands store the contents of the SC in the mark place register (MPR) at the 3/4-cycle time. At the beginning of the next program cycle, the memory bits are transferred to the SC, and the MPR is incremented.

At the end of the sequence to which a branch was made, a return command (RTN) transfers the contents to MPR to the SC, and the main sequence continues at L + 1.

JUMP

Mnemonic: JMP

Command Code: 05_8

The JMP command transfers memory bits to the SC at the beginning of the next program cycle.

TRANSFER

Mnemonic: TRF

Command Code: 06_8

The TRF command performs data transfers between certain arithmetic and instrumentation registers. Two or more transfers may be programmed at one time. All transfers start at the 3/4-program cycle time and are completed at the beginning of the next program cycle.

RESET

Mnemonic: RES

Command Code: 07_8

The RES command places the measurement section registers in a particular state. The states of these registers are of consequence as they are used to "condition" the measurement section. For example, the

contents of the accumulator prior to a frequency or period measurement determine the voltage threshold the input must attain to be counted as an event.

LOAD SCRATCH PAD

Mnemonic: LSP

Command Code: 10_8

The LSP command transfers memory bits to scratch pad memory location SP(1). Data from this register can be transferred to certain registers as determined by the TRF command, or they can be transferred successfully to three other scratch pad locations as determined by the Rotate Scratch Pad (RSP) command. Transfer of data from SP(1) is nondestructive.

TRACK AND HOLD

Mnemonic: TAH

Command Code: 11_8

The TAH command causes the track and hold control to anticipate the occurrence of certain timing pulses which initiate and terminate the track and hold function automatically.

During the track operation, a two-channel amplifier tracks (or follows) the voltage functions obtained from the remote unit selected by the SRU command.

During the hold function, both amplifiers are caused to hold to the voltage level present at the instant the hold is begun. The held voltage drifts at the rate of about 1 millivolt per millisecond. The amplifiers, channel A and channel B units, are selectable by the use of the Select Channel Command (SCH).

HOLD

Mnemonic: HLD

Command Code: 128

The HLD command terminates the track operation of the track and hold amplifiers when it is placed in the immediate track mode by the TAH

command. The use of this command is primarily for the purpose of measuring dc or slowly varying voltages not having a carrier frequency.

The hold command is issued just prior to a voltage-to-digital conversion (VDC).

FREQUENCY MEASUREMENT

Mnemonic: FRM

Command Code: 13_8

The FRM command determines the number of positive-going threshold crossings that an input voltage makes for a predetermined time period or aperture. The aperture has a maximum value of 3.6700 seconds and a minimum value of 504 microseconds.

Threshold crossings are counted at a maximum rate of 250 KHz (limit of measurement amplifiers) by the time-frequency counter which has as a limit 8191 counts and an accuracy of 7 ±1/2 count. The count is transferred to scratch pad memory location (SP) at the completion of the measurement process.

The measurement section produces a measurement busy signal (see SKS command) which is "0" during the frequency measurement and returns to a "1" after the process is terminated. This signal may be addressed by the SKS function to determine whether the process has been completed.

The threshold from which the input crossings are based is the numerical value in millivolts contained in the accumulator at the time of the FRM command. The threshold may be programmed by LSP, TRF (S/A) commands prior to FRM, or set to 0 volts by the RES command. The accumulator is automatically reset to "0" after a Record and Reset (RWR) command. The threshold range may be programmed from -4.096 volts to +4.095 volts in 1-millivolt steps. The incoming signal (after scaling by remote unit) is compared with the threshold and counted as an event when it exceeds the threshold by 1 millivolt.

SELECT CHANNEL

Mnemonic: SCH

Command Code: 14_8

The SCH command determines which of the two track and hold amplifiers is connected to the decision amplifier. The selected channel will remain

operative until reslection. When the CAPA system is first energized, the initial clear selects the A channel.

PERIOD MEASUREMENT

Mnemonic: PDM

Command Code: 15_8

The PDM command causes the time-frequency counter to be incremented at a 1-MHz rate for a time period of from one to eight signal periods. Because the time-frequency counter has a maximum value of 8191 counts, it will be filled in 8.19×10^{-3} seconds. The 1-MHz clock is accurate to one part in 10^6.

To prevent the possibility of the measurement system not completing its function due to the absence of an input signal, there is an automatic "short" 20 milliseconds after the PDM command has been issued. The process generates a measurement busy signal which is equal to "0" during the measurement and returns to a "1" after completion of measurement or an aborted measurement. The contents of the time-frequency counter are transferred to SP after the measurement is complete. The threshold voltage which determines the beginning and end of single input cycles is programmable in the same manner as described in the FRM section.

TIME PERIOD MEASUREMENT

Mnemonic: TPM

Command Code: 16_8

The TPM command causes the time-frequency counter to begin counting at a 1-MHz rate when an incoming signal crosses a threshold in the positive going direction. It stops counting when another signal reaches the same threshold.

One of the signals is produced by the channel A amplifier, and the other by the channel B amplifier. Either amplifier output can be selected as the event which starts the counting process. The other channel is then automatically enabled to produce the terminating event. The time resolution is ± 0.5 microsecond or ± 0.072 electrical degree when measuring the phase difference between two 400-Hz sinusoids. This command would be suitable for measuring the time between any two events where the time separation is less than 8.191×10^{-3} seconds.

ROTATE SCRATCH PAD

Mnemonic: RSP

Command Code: 20_8

The RSP command rotates the contents of a six-word (13-bit words) scratch pad memory by moving all words simultaneously.

Access to scratch pad memory is by SP(1) only, so that loop counts, intermediate results, or other temporary data are recalled by shifting the correct number of times to bring the desired word into the SP(1) position.

Results of measurement commands always appear in SP(1) so the scratch pad must be rotated in order to save the contents of SP(1).

VOLTAGE TO DIGITAL CONVERSION

Mnemonic: VDC

Command Code: 21_8

The VDC command causes a voltage ratio-to-digital conversion process, wherein the channel switch output, unknown voltage, and a programmed voltage are factors in the ratio. The results of the conversion appear in the accumulator and in SP(1).

RECORD WORD AND RESET

Mnemonic: RWR

Command Code: 22_8

The RWR command transfers one or all scratch pad words to a record buffer register and records these words on 1/2-inch magnetic tape. When no data is presented to the recorder, fictitious words (100 000 000 000) are recorded.

The record circuits add "1" to a data word in case the data word is equal to the fictitious word.

GENERATE RECORD GAP

Mnemonic: GRG

Command Code: 23_8

The GRG command generates and records a special five-character group followed by approximately 2/3-inch of tape with characters which contain only "0's". One of the five characters is used to mark the end of a block of data, and the gap containing all zeros allows stopping and starting of the magnetic tape recorder.

RETURN

Mnemonic: RTN

Command Code: 24_8

The RTN command causes the contents of the mark place register to be transferred to the sequence counter at the beginning of the next program cycle time. The result is that the program continues from the step L + 1, where L is the location of the last MPB command.

This command can be used as the last step in a sub-sequence to return to the main sequence of commands.

CONDITIONAL JUMP

Mnemonic: CJP

Command Code: 25_8

This command jumps the sequence counter to the location determined by the operand if the accumulator sign bit is zero. Otherwise, no operation occurs (pass instruction).

ROTATE-LOAD SCRATCH PAD

Mnemonic: RLD N

Command Code: 26_8

This command rotates the array of six scratch pad locations one position and loads scratch pad 1 with the number N.

COMPUTE

Mnemonic: COM

Command Code: 30_8

The COM command causes the contents of the scratch pad memory location SP1 to be added to or subtracted from the contents of the accumulator.

APPENDIX V

DEMONSTRATION TEST FLIGHT ANALYSIS

BACKGROUND

The philosophy governing the demonstration flight test required that the reconnaissance sensors being monitored be used in the normal manner and that maintenance actions proceed as if CAPA were nonexistent. The maintenance actions and sensor performance was then compared with the CAPA messages. The following records were kept:

- CAPA in-flight generated messages
- A record of all CAPA measurements and decisions for each flight on magnetic tape
- A pilot's test log for each flight (Shaw AFB Form 033)
- A photointerpreter's analysis of each flight
- A record of all maintenance actions, including man-hours at the flight line and at the shop

The CAPA results were compared with the maintenance actions and scored. A summary of the scoring groundrules follows:

- Events -- An event will be considered to have occurred each time the status of a monitored system changes. If the status of any given line replaceable unit (LRU) changes more than twice during a flight, this will be considered an intermittent condition and will constitute a single event. Likewise, a failure of the CAPA will be considered a single event.
- Grading -- Each flight will be reconstructed from the maintenance and photointerpreter results and from the CAPA data. These two reconstructions will be compared, and whenever possible the CAPA will be graded on each event that occurred. The CAPA will be given a positive (+) grade if the decision made by the CAPA was correct and a negative (-) grade if the CAPA's decision was incorrect.
- CAPA Evaluations -- Full success will be considered achieved if the CAPA performs a correct diagnosis to the LRU in 80 percent of the malfunctions that occur in the

AN/APQ-102 radar mapping and AN/AAS-18 infrared reconnaissance sets. A separate determination will be made for the KS72A camera and the AN/ASN-56 inertial navigation set to the extent the data permits. To determine the confidence level of the CAPA, the total number of positive (+) events will be divided by the total number of events both positive and negative for each flight.

Figure 14 is a bar chart showing the scores for each flight. The average score is 91.9 percent; this does not include flight 1, since CAPA was not operational on that flight. If at worst-case flight 1 was given a score of zero and averaged with the others, the average score would be reduced by only three percent.

The Test Flight Log, Table I, contains additional information about the test flights. The data, flight number, sensors used, and duration of each test flight is shown in the table, along with the actual number of failures detected by the CAPA and the number of times that the CAPA detected a signal which had violated its normal limits. For the purpose of this report, a failure or malfunction is an abnormal condition in one of the aircraft reconnaissance sensors which either caused a degradation in sensor performance or is forbidden by definition; that is, a power supply which is specified to have a voltage tolerance of 1 percent is considered to have failed if the voltage exceeds that amount, regardless of whether or not sensor performance is sufficiently degraded to affect sensor output adversely. A limit violation is a condition in which a variable signal passes beyond the limits which were specified for it, based on information from the data gathering flights.

Further explanation of the failures in Table I is contained in Table II, Abnormal Operating Conditions; Table III, Malfunction Requiring Hardware Repair; and Table IV, Malfunctions Not Requiring Hardware Repair.

COMPARISON OF ACTUAL SLR MAINTENANCE DATA WITH THAT USED IN PLANET MODEL

Mean-Time-Between-Failure

The demonstration phase of the CAPA program encompassed 51.02 flight hours, with 20 separate maintenance actions required to sustain the flights. This yields a calculated MTBF (in accordance with AFM 66-1) of 2.55.

The model MTBF was 2.8 for the simulation without the CAPA using AFM 66-1 data factored to include only sensor operating hours.

The effective MTBF of the side-looking radar (SLR) without the inclusion of false removal maintenance actions was 3.64 for a CAPA/no-CAPA ratio of 1.426. The ratio used in the model was 1.667, for an improved MTBF (with CAPA) of 4.66.

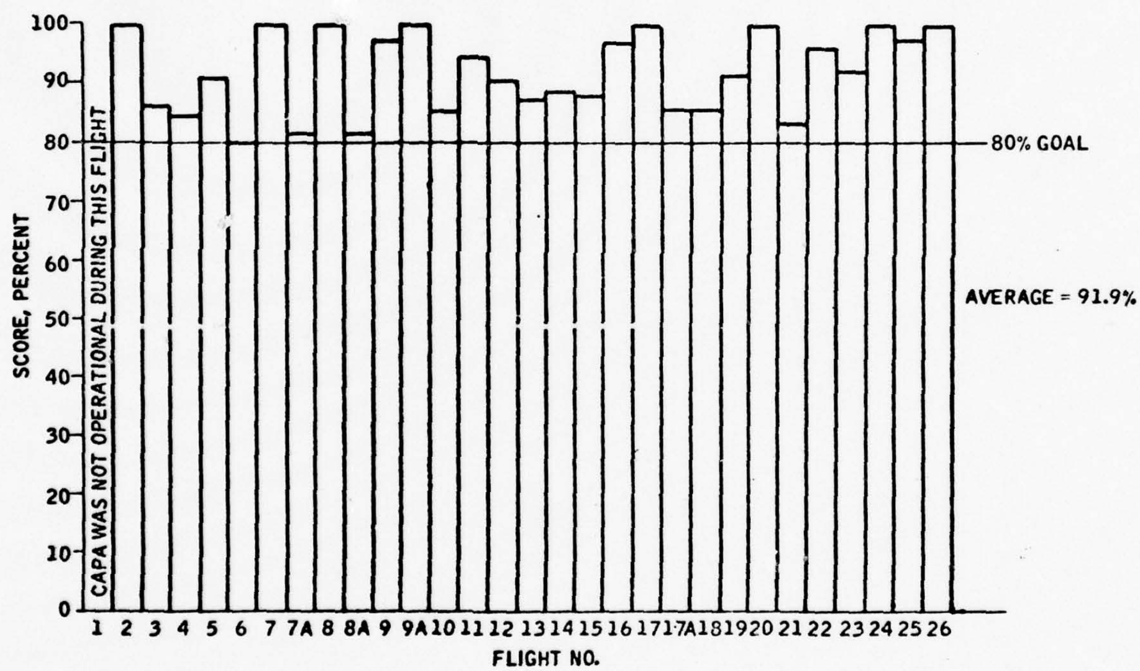

Figure 14. CAPA Test Flight Scores

Table I. Test Flight Log Sheet

Flight Date[a]	Flight No.	SLR	IR	KS72	Time (minutes)	Failure	Limit Violation	Score	Remarks
March 27	1	X	X	X	47.1	---	---	None	CAPA was not operational during this flight.
April 2	2	---	---	X	37.4	1	0	100.0	CAPA failed.
May 2	3	X	X	X	58.1	2	8	86.4	Ground speed too slow; left AGC too high.
May 3	4	X	X	X	71.5	2	6	84.6	SLR film runout; IR pitch limit exceeded (1).
May 8	5	X	X	X	72.3	1	3	90.6	SLR BIT switch in "T PWR".
May 21	6	---	X	X	82.3	0	0	80.0	
May 22	7	---	X	X	73.9	0	1	100.0	
May 23	7A	---	X	X	93.0	0	2	81.8	
May 23	8	---	X	X	82.2	0	2	100.0	
May 27	8A	---	X	X	96.7	0	3	81.3	
June 4	9	X	X	X	88.6	1	5	97.3	Bad left I. F. tube.
June 6	9A	X	---	---	33.0	1	0	100.0	SLR recorder control disconnected.
June 14	10	X	X	X	21.6	8	2	85.3	KS72 disconnected; IR 2.5 vdc; SLR saturated (4); SLR BIT switch in "T PWR"; right AGC too high.
June 20	11	X	X	---	78.0	2	6	94.7	SLR film runout; SLR BIT switch in "T PWR".
June 20	12	X	X	X	88.3	1	6	90.5	SLR film runout.
June 25	13	X	X	---	68.4	1	0	87.5	SLR pressure leak.
June 26	14	X	X	X	76.7	1	3	88.9	SLR film runout.
June 26	15	X	X	---	71.2	6	1	88.3	SLR saturate (2); roll limit exceeded (3); IR cool-down failure.
June 27	16	X	X	---	91.1	10	5	97.3	SLR saturate (3); roll limit exceeded (7).
June 27	17	X	X	---	54.9	1	1	100.0	SLR standby not selected.
July 1	17A	---	X	X	53.4	0	0	85.7	
July 26	18	X	X	---	89.7	1	1	85.7	SLR CB 337 open.
July 26	19	X	X	---	52.1	2	2	88.0	SLR saturate (2).
July 29	20	X	X	X	62.2	2	3	100.0	SLR BIT switch in "L CRT"; SLR roll limit exceeded (1).
August 1	21	X	X	---	90.6	1	14	83.4	IR pitch limit exceeded (1).
August 1	22	X	X	---	58.3	1	4	96.8	SLR saturate.
August 2	23	X	X	X	67.4	4	11	92.0	IR 2.5 vdc (3); SLR 140 MHz (1).
August 2	24	X	X	X	56.4	3	3	100.0	IR 2.5 vdc (3).
August 7	25	X	X	X	83.3	2	6	97.8	IR cool-down (1); IR power fail-induced (1).
September 16	26	X	---	---	25.0	2	0	100.0	SLR frequency converter transmitter (1); KS72 disconnected.

[a]All dates are 1968.

Table II. Abnormal Operating Conditions

Flight Date[a]	Condition	Degradation	CAPA Detected
May 8	SLR BIT switch in "T PWR" position	None	Yes
June 14	KS72 test cable disconnected	None	Yes
June 14	SLR BIT switch in "T PWR" position	None	Yes
June 20	SLR BIT switch in "T PWR" position	None	Yes
July 29	SLR BIT switch in "L CRT" position	None	Yes

[a]All dates are 1968.

Table III. Malfunctions Requiring Hardware Repair

Repair Date[a]	Maintenance Required	Degradation	CAPA Detected
May 8	Adjust left antenna switch arm	None	No
May 9	Repair intermittent saturate relay	Slight	No
May 9	Adjust video clutterlock gain	Moderate	Yes
June 6	Connect recorder control	Severe	Yes
June 13	Adjust focus	Slight	No
June 13	Replace left I. F. tube	Moderate	Yes
June 17	Adjust video clutterlock	Moderate	Yes
June 17	Replace self-verification assembly	None	No
June 17	Replace left chirp network	Slight	No
June 25	Repair pressure leak	Severe	Yes
August 2	No IR 2. 5 vdc (induced 3 times flight 23)	Severe	Yes
August 2	SLR-induced failure (3 times flight 23)	Severe	Yes
August 2	No IR 2. 5 vdc (induced 3 times flight 24)	Severe	Yes
August 7	IR power failure (induced)	Severe	Yes
August 7	SLR-induced failure (2 times flight 24)	Severe	Yes
August 7	SLR reference computer failure 140-MHz pulse	Severe	Yes
Sept 16	SLR frequency converter transmitter failure	Severe	Yes

[a]All dates are 1968.

Table IV. Malfunction Not Requiring Hardware Repair

Flight Date[a]	Malfunction	Degradation	CAPA Detected
May 2	Ground speed too slow	Slight	Yes
May 3	SLR film runout	Severe	Yes
May 3	IR pitch limit exceeded	Moderate	Yes
May 8	IR pitch limit exceeded	Moderate	Yes
May 27	IR pitch limit exceeded	Moderate	Yes
June 14	SLR saturate (3 times)	Slight	Yes
June 14	IR 2. 5 vdc out-of-tolerance	Severe	Yes
June 20	IR 2. 5 vdc out-of-tolerance (50 minutes)	None	Yes
June 20	IR 2. 5 vdc out-of-tolerance (62 minutes)	None	Yes
June 20	SLR film runout (flight 11)	Severe	Yes
June 20	SLR film runout (flight 12)	Severe	Yes
June 26	SLR film runout	Severe	Yes
June 26	SLR saturate (2 times)	Slight	Yes
June 26	SLR roll limit exceeded (3 times)	Moderate	Yes
June 26	IR momentary cool-down failure	Severe	Yes
June 27	IR 2. 5 vdc out-of-tolerance (50 minutes)	None	Yes
June 27	SLR saturate (3 times)	Slight	Yes
June 27	SLR roll limit exceeded (7 times)	Moderate	Yes
June 27	SLR standby not selected	Severe	Yes
July 26	No SLR 14/28 vac (CB 337, flight 18)	Slight	Yes
August 1	SLR saturate (flight 22)	Slight	Yes
August 1	IR pitch limit exceeded (flights 21 and 22)	Moderate	Yes
August 7	IR cool-down failure (secondary-induced)	Severe	Yes
Sept. 16	KS72 camera disconnected	Severe	Yes

[a]All dates are 1968.

Flight Line Maintenance Time

The time spent at the RF4C flight line consumed 8 hours or less 80 percent of the time. The model also used a flight line maintenance time of 8 hours or less 80 percent of the time.

Improvement in Flight Line Maintenance Time

The improvement in flight line maintenance time due to false removals alone was 21.6 percent (i.e., from 37 hours to 29 hours). The model simulated this improvement by the increase in effective MTBF (previously discussed). Estimates for the amount of time potentially saved at the flight line due to the diagnostic ability of the CAPA yields an additional saving of 25.7 percent. The total potential line time saving is thus 47.3 percent due to the CAPA-induced decrease in false removals and to the speedup in detecting the malfunctioning unit.

Bench Repair Time Improvement

The bench repair time due to false removals comprised 14.6 percent of the total bench repair time; this represents a potential savings if the CAPA were used to pinpoint actual failures. The model did not simulate bench repair time to a large extent, since it had no effect on aircraft availability, as the spares level was sufficient to fulfill all maintenance demands. However, in a practical situation such a savings (14.6 percent) could well mean a sizable reduction in spares required to support a given number of aircraft.

TEST FLIGHT SUMMARIES

CAPA Test Flight 1 (27 March 1968)

The CAPA central processor was not operational during this flight. ON times for this flight were as follows:

CAPA:	47.1 minutes
Camera:	Unknown
SLR:	Unknown
IR:	Unknown

CAPA Test Flight 2 (2 April 1968)

The CAPA self-test correctly indicated that a portion of the central processor circuitry was not operating properly during this flight and terminated further testing of the aircraft systems. The CAPA was returned to Minneapolis for adjustment following this flight.

ON times for this flight were as follows:

CAPA:	37.4 minutes
Camera:	Unknown
SLR:	Unknown
IR:	Unknown

CAPA Test Flight 3 (2 May 1968)

The CAPA indicated that the aircraft was flying slower than the limits established for the SLR during the data gathering phase of the program. It also indicated an excessive left automatic gain control (AGC) signal, which was corrected by an adjustment to the SLR on 9 May.

ON times for this flight were as follows:

CAPA:	44.5 minutes
Camera:	44.5 minutes
SLR:	36.2 minutes
IR:	44.5 minutes

CAPA Test Flight 4 (3 May 1968)

The CAPA correctly indicated that the SLR film had stopped running during this flight. It also confirmed the SLR AGC failure detected during flight 3. The IR pitch limits were exceeded during this flight, and this violation was indicated by the CAPA.

ON times for this flight were as follows:

CAPA:	70.5 minutes
Camera:	70.5 minutes
SLR:	43.2 minutes
IR:	70.5 minutes

CAPA Test Flight 5 (8 May 1968)

The CAPA correctly indicated that the RF Power Monitor signal was absent. This was caused by the BIT (built-in test) select switch being in the "T PWR" position, thus effectively grounding the test point through the BIT meter.

ON times for this flight were as follows:

CAPA:	72.3 minutes
Camera:	56.4 minutes
SLR:	35.4 minutes
IR:	47.2 minutes

CAPA Test Flight 6 (21 May 1968)

No significant events occurred or were indicated by the CAPA during this flight.

ON times for this flight were as follows:

CAPA:	82.3 minutes
Camera:	82.3 minutes
SLR:	0.0 minutes
IR:	78.9 minutes

CAPA Test Flight 7 (22 May 1968)

No significant events occurred or were indicated by the CAPA during this flight.

ON times for this flight were as follows:

CAPA:	72.0 minutes
Camera:	72.0 minutes
SLR:	0.0 minutes
IR:	64.6 minutes

CAPA Test Flight 7A (23 May 1968)

No significant events occurred or were indicated by the CAPA during this flight.

ON times for this flight were as follows:

CAPA:	92.0 minutes
Camera:	92.0 minutes
SLR:	0.0 minutes
IR:	79.3 minutes

CAPA Test Flight 8 (23 May 1968)

No significant events occurred or were indicated by the CAPA during this flight.

ON times for this flight were as follows:

CAPA:	63.0 minutes
Camera:	0.0 minutes
SLR:	0.0 minutes
IR	63.0 minutes

CAPA Test Flight 8A (27 May 1968)

No LRU failures were detected by the CAPA during this flight; however, the CAPA did indicate very erratic conditions on the IR 2.5-vdc power supply test point.

ON times for this flight were as follows:

CAPA:	94.0 minutes
Camera:	94.0 minutes
SLR:	0.0 minutes
IR:	92.0 minutes

CAPA Test Flight 9 (4 June 1968)

The CAPA indicated that the Video "A" signal was too low. This condition was caused by a weak intermediate frequency amplifier tube which was replaced on 13 June, thereby improving the quality of the SLR film. The 2.5-vdc signal which was erratic in flight 8A was more stable during this flight, but the nominal voltage appeared to have been shifted downward by approximately 0.25 volt.

The ON times for this flight were as follows:

CAPA:	83.6 minutes
Camera:	88.6 minutes
SLR:	29.3 minutes
IR:	56.0 minutes

CAPA Test Flight 9A (6 June 1968)

The CAPA correctly indicated that the SLR was unable to become ready during this flight because of a disconnected SLR recorder control cable.

ON times for this flight were as follows:

CAPA:	33.0 minutes
Camera:	0.0 minutes
SLR:	0.0 minutes
IR:	0.0 minutes

CAPA Test Flight 10 (14 June 1968)

The CAPA correctly indicated that the KS72 camera/CAPA interface cable was disconnected. The CAPA also indicated that the SLR integrating capacitors had saturated four times and that the SLR BIT select switch was in the "T PWR" position, which effectively grounded the test point

through the BIT meter. A malfunction in the SLR right AGC circuitry was also indicated by the CAPA. This circuitry was adjusted on 17 June, and the problem did not reappear thereafter. The IR 2.5-vdc signal was out-of-tolerance throughout most of the flight. This caused severe degradation of the IR film.

ON times for this flight were as follows:

CAPA:	21.0 minutes
Camera:	Unknown
SLR:	17.0 minutes
IR:	14.8 minutes

CAPA Test Flight 11 (20 June 1968)

The CAPA correctly indicated that the SLR film had a film runout during this flight and that the SLR RF Power Monitor signal was absent because the BIT selector switch was in the "T PWR" position.

ON times for this flight were as follows:

CAPA:	78.0 minutes
Camera:	0.0 minutes
SLR:	29.6 minutes
IR:	76.2 minutes

CAPA Test Flight 12 (20 June 1968)

The CAPA correctly identified a SLR film runout during this flight.

ON times for this flight were as follows:

CAPA:	88.3 minutes
Camera:	88.3 minutes
SLR:	49.7 minutes
IR:	76.1 minutes

CAPA Test Flight 13 (25 June 1968)

The CAPA correctly indicated that the SLR was unable to become ready. This was confirmed by post-flight servicing which discovered and repaired an SLR pressure leak.

ON times for this flight were as follows:

CAPA:	68.4 minutes
Camera:	0.0 minutes
SLR:	0.0 minutes
IR:	17.9 minutes

CAPA Test Flight 14 (26 June 1968)

The CAPA correctly identified an SLR film runout during this flight.

ON times for this flight were as follows:

CAPA:	95.0 minutes
Camera:	76.5 minutes
SLR:	32.5 minutes
IR:	75.3 minutes

CAPA Test Flight 15 (26 June 1968)

The CAPA correctly indicated that the SLR integrating capacitors had become saturated two times and that the aircraft had exceeded the SLR roll limits three times. The CAPA also indicated that the IR had not cooled down until 4.2 minutes after the pilot had enabled the IR.

ON times for this flight were as follows.

CAPA:	71.0 minutes
Camera:	0.0 minutes
SLR:	34.6 minutes
IR:	2.3 minutes

CAPA Test Flight 16 (27 June 1968)

The CAPA correctly indicated an SLR saturate condition three times and that the SLR roll limits were exceeded seven times.

ON times for this flight were as follows:

CAPA:	91.0 minutes
Camera:	0.0 minutes
SLR:	43.0 minutes
IR:	24.7 minutes

CAPA Test Flight 17 (27 June 1968)

The CAPA correctly indicated that the SLR was not operated during the entire flight.

ON times for this flight were as follows:

CAPA:	54.7 minutes
Camera:	0.0 minutes
SLR:	0.0 minutes
IR:	12.1 minutes

CAPA Test Flight 17A (1 July 1968)

No significant events occurred or were indicated by the CAPA during this flight.

ON times for this flight were as follows:

CAPA:	53.4 minutes
Camera:	53.4 minutes
SLR:	0.0 minutes
IR:	53.4 minutes

CAPA Test Flight 18 (26 July 1968)

The CAPA correctly indicated that the SLR 14/28-vac indicator voltage was absent. Since this is a requirement for complete operation of the SLR, the SLR was not considered to be ready; however, the SLR was operated without the indicator lights. Severe near-range washout on the film was probably caused by saturation which was not indicated on the pilot's control panel because of the absense of the 14 and 28 volts ac.

ON times for this flight were as follows:

CAPA:	89.7 minutes
Camera:	0.0 minutes
SLR:	5.3 minutes
IR:	89.7 minutes

CAPA Test Flight 19 (26 July 1968)

The CAPA correctly identified an SLR saturate condition during this flight.

ON times for this flight were as follows:

CAPA:	52.1 minutes
Camera:	0.0 minutes
SLR:	29.6 minutes
IR:	9.3 minutes

CAPA Test Flight 20 (29 July 1968)

During this flight, the CAPA correctly indicated that the SLR roll limits had been exceeded and that the BIT select switch was in the "L CRT" position, thus degrading the signal at the test point.

ON times for this flight were as follows:

CAPA:	62.2 minutes
Camera:	62.2 minutes
SLR:	26.2 minutes
IR:	61.8 minutes

CAPA Test Flight 21 (1 August 1968)

The CAPA correctly indicated that the IR pitch limit had been exceeded during this flight.

ON times for this flight were as follows:

CAPA:	90.6 minutes
Camera:	0.0 minutes
SLR:	64.0 minutes
IR:	34.8 minutes

CAPA Test Flight 22 (1 August 1968)

The CAPA correctly indicated that the SLR had become saturated during this flight.

ON times for this flight were as follows:

CAPA:	58.3 minutes
Camera:	0.0 minutes
SLR:	15.6 minutes
IR:	34.8 minutes

CAPA Test Flight 23 (2 August 1968)

During this flight, the CAPA correctly identified three blank spaces on the SLR film due to pilot-induced failures. Also during this flight, the CAPA correctly identified three failures induced in the IR.

ON times for this flight were as follows:

CAPA:	67.4 minutes
Camera:	66.7 minutes
SLR:	27.5 minutes
IR:	57.3 minutes

CAPA Test Flight 24 (2 August 1968)

The CAPA correctly identified three pilot-induced failures in the IR during this flight. It also indicated two blank spaces on the SLR film due to pilot-induced failures. It further indicated that the second pilot-induced failure was not corrected for the duration of the flight, probably because of a real failure propagated by the pilot-induced failure.

ON times for this flight were as follows:

CAPA:	56.4 minutes
Camera:	56.4 minutes
SLR:	16.1 minutes
IR:	28.2 minutes

CAPA Test Flight 25 (7 August 1968)

During this flight, the CAPA indicated a power failure which was induced in the IR. It also indicated a subsequent cool-down failure resulting from the induced power failure. The CAPA also confirmed the failure detected in flight 24, indicated by the absence of the 140-MHz pulse. The indication was confirmed by a complete absence of images on the SLR film for the entire flight.

ON times for this flight were as follows:

CAPA:	83.3 minutes
Camera:	83.3 minutes
SLR:	23.6 minutes
IR:	3.7 minutes

CAPA Test Flight 26 (16 September 1968)

During this flight, the CAPA correctly indicated that the SLR frequency converter transmitter had failed and that the KS72 camera/CAPA interface cable was disconnected.

ON times for this flight were as follows:

CAPA:	25.0 minutes
Camera:	Unknown
SLR:	12.1 minutes
IR:	0.0 minutes

APPENDIX VI

OPERATIONAL BENEFITS

A mathematical study of the impact of CAPA on operational and economic factors was performed using a model called PLANET (Planned Analysis and Evaluation Technique). The basic purpose of this study was to duplicate a real-life situation with a computer so that changes to the situation could readily be studied. Within reason, the model reflects real-life experience. An exact analog with real life is not necessary, however, since normally only changes to a nominal situation are being investigated; the "relative" effect of changes may be studied even though the "absolute" base might not be quite right.

The validation and verification of the model are discussed in the paragraphs that follow.

SCENARIO

The scenario considered represents a short-term span of intensified reconnaissance activity. The maximum usage scenario was selected for the following reasons:

- The effects due to the Central Airborne Performance Analyzer (CAPA) are more readily determined by analyzing the scenario selected.
- The results from the study are representative of the results which would be achieved if other scenarios were studied.
- The results, with scaling, apply quite well to any quick-response reconnaissance concepts.

The scenario selected represents a satisfactory framework for evaluating the effectiveness of a CAPA system; the results obtained are believed to accurately reflect tactical experience in other scenarios.

FAILURE RATES

All maintenance actions for the RF4C aircraft were considered at the two- and three-digit work unit code level so that the "fine-grain" structure of maintenance could be considered. The intent in the study model was to duplicate, as closely as possible, the number (and type, in general) of failures and maintenance actions which might be expected during real life for each work unit code. Data for approximately 240 RF4C aircraft over six months of operation (50,911 flight hours) was taken as representative. The model, over 1326 simulated flight hours, duplicated these real-life

failure rates with a correlation coefficient of 0.78 over 30 work unit codes, as shown in Figure 15. This correlation is considered to be excellent, and suggests that the maintenance actions being performed on each aircraft in the model quite accurately reflect real-life maintenance experience.

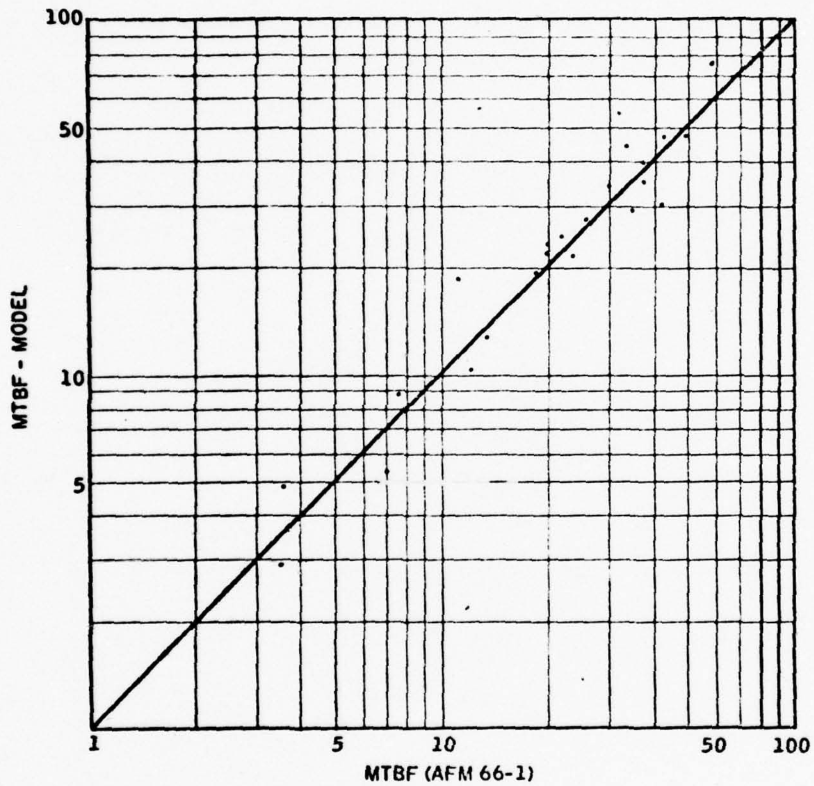

Figure 15. Comparison of AFM 66-1 Reliability by Work Unit Code with Model Results

In Table V, note the specific agreement between the model and AFM 66-1 experience.

Table V. Comparison of Flight Line Maintenance Man-Hours Per Flight Hour (MMH/FH), AFM 66-1 and Model

Source	Nonreconnaissance		Reconnaissance		Total	
	Flight Hours	MMH/FH	Flight Hours	MMH/FH	Flight Hours	MMH/FH
Study no. 1	656	5.97	656	2.44	656	8.41
Study no. 2	670	5.65	656	2.44	670	8.09
Total	1,326	5.81	1,312	2.44	1,326	8.25
AFM 66-1	50,911	5.96	50,911	2.70[a]	50,911	8.66

[a]2.20 from AFM 66-1 ±0.50 estimated for nonreported systems.

Comparison Basis

Two complete studies were made with the input data changed as described earlier. Each study ran for approximately 100 minutes on a CDC 3600 digital computer and used most of the 131,000 words of core memory available. With approximately the same running time, the model simulated four days and seven days of operation for studies 1 and 2 respectively (without CAPA, and CAPA on six systems) due to respectively fewer failures per flight.

The first three days of flights were taken as a basis for comparing the effect of the CAPA over the two studies. This represented 762 scheduled flight hours per study. Tests to determine the reliability of the data output, like the comparison with AFM 66-1 shown previously, indicate that these limited computer runs do produce data that can be validly extrapolated.

Study Results

The computer study outputs were analyzed in detail for each study to obtain as much information as possible and to make comparisons between studies. This section presents the results of this analysis.

AVAILABILITY

Airborne performance analysis and fault-isolation (with CAPA) affects two parameters which ultimately influence aircraft availability:

- Greater in-flight effective reliability of monitored systems results in less maintenance, quicker turnaround.

- Decreased maintenance time for monitored systems (due to automatic fault-isolation during flight) results in more rapid turnaround.

The effect of the CAPA on aircraft availability was investigated by determining the percentage of scheduled flights flown as a function of wing size for the two simulations. Figure 16 presents this data.

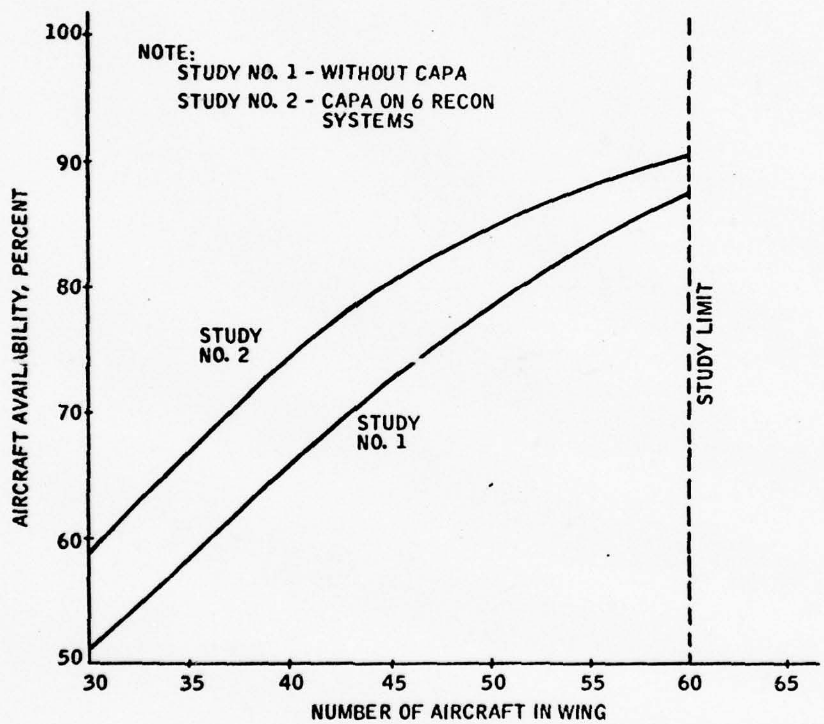

Figure 16. Aircraft Availability versus Wing Size (Study Results)

From Figure 16 it may be seen that the availability of a 55-aircraft wing equipped with the CAPA is equal to the availability of a 60-aircraft wing not equipped with the CAPA. At the 40-aircraft wing level, the improvement in availability is more dramatic; i. e., 34 CAPA-equipped aircraft are the equivalent of 40 non-CAPA-equipped aircraft.

A quick-response reconnaissance squadron of six RF4C aircraft was suggested, where six aircraft and associated support equipment would be ready to fly into any suitable base to provide a rapid reconnaissance capability for that base. Although not explicitly studied, the results of this study indicate that the same reconnaissance coverage might be achieved with a squadron of only five RF4C aircraft equipped with a CAPA system, or a significant improvement in operational effectiveness if six aircraft are used.

MANPOWER REQUIREMENTS

The flight line maintenance manpower requirements for the RF4C were divided into 15 different manpower types, described by their Air Force specialty codes (AFSC). Of these 15 types, 12 are associated with work unit codes not affected by a CAPA system (i. e., nonreconnaissance systems). These are used to study the variability of the model between studies, since the tasks they perform are not changed between studies. Three of the manpower types are connected with reconnaissance systems and do change between studies.

Utilization

Table VI presents manpower utilization by AFSC during the first three days of the two studies conducted. It is apparent that considerable day-to-day variation in manpower utilization exists, due to the random nature of the failures which generate the maintenance demands. This table includes the effect of task flexibility of some of the personnel types, and thus direct comparison with failure type cannot be made.

Table VII presents a more meaningful summary of the man-hours required. It is apparent that although daily variations are present, the overall results are consistent (nonreconnaissance systems). From this table the effect of the CAPA on maintenance man-hours per flight hour (MMH/FH) for the reconnaissance system can be seen, with a 51 percent reduction between studies 1 and 2 (2. 44 to 1. 20). The figures in Table VII are directly related to flight hours and indicate the effect of reduced flight line maintenance time on the systems monitored by a CAPA system. The data may be considered to be independent of the particular scenario chosen.

SPARES

For simplicity, the studies assumed that a spare was required for each maintenance action, and sufficient spares were provided so that an out-of-spares condition (requiring the aircraft to sit idle until available) would not occur. As can be seen, this assumption is the same as if no spare were required in terms of maintenance action, but allows a study of

Table VI. Daily Manpower Utilization by AFSC

Description	AFSC	Daily Manpower Utilization Rate						Available per Shift
		Study No. 1[a]			Study No. 2[b]			
		Day 1	Day 2	Day 3	Day 1	Day 2	Day 3	
Nonreconnaissance systems	431 x 1	0.40	0.43	0.59	0.38	0.62	0.56	20
	424 x 0	0.06	0.41	0.44	0.12	0.27	0.24	8
	422 x 3	0.64	0.59	0.81	0.52	0.66	0.63	10
	432 x 0	0.12	0.41	0.17	0.14	0.38	0.36	9
	423 x 2	0.06	0.41	0.44	0.12	0.27	0.24	8
	423 x 0	0.60	0.72	0.90	0.72	0.92	0.77	10
	421 x 2	0.55	0.71	0.95	0.66	0.79	0.72	10
	422 x 1	0.14	0.61	0.44	0.08	0.36	0.42	6
	422 x 2	0.09	0.58	0.75	0.29	0.36	0.99	6
	431 x 0	0.41	0.42	0.47	0.29	0.50	0.49	10
	325 x 0	0.26	0.75	0.96	0.20	0.17	0.05	4
	422 x 0	0.27	0.60	0.42	0.30	0.68	0.53	10
Reconnaissance systems	301 x 4	0.45	0.71	0.84	0.29	0.51	0.33	24
	301 x 3	0.00	0.65	0.18	0.02	0.03	0.07	2
	402 x 0	0.37	0.47	0.53	0.13	0.17	0.21	14

[a]Without CAPA.

[b]With CAPA on six recon systems.

Table VII. Flight Line Maintenance Man-Hours (Study Results)

Source	Flight Hours	Man-Hours			MMH/FH		
		Nonrecon	Recon	Total	Nonrecon	Recon	Total
Study no. 1[a]	656	3919.40	1587.51	5506.91	5.97	2.44	8.41
Study no. 2[b]	670	3790.30	802.83	4593.13	5.65	1.20	6.85

[a]Without CAPA.

[b]With CAPA on six recon systems.

spares flow required to support each type of maintenance action. (These spares are line replaceable units and should not be related to module or subassembly-type spares.)

It is apparent that some spares provisioning is required (or cannibalization) for maximum aircraft utilization. It is not economically sound to have highly expensive RF4C aircraft idle, awaiting shop repair of some system because a spare was unavailable; in effect, the spare at that point is worth the cost of an aircraft. On the other hand, full provisioning of spares is also prohibitively expensive and difficult to achieve logistically in the field. In practice, some compromise solution is generally used which is more practical than optimum.

The daily spares requirement for each work unit code was analyzed to determine the minimum number of spares which would have been required to maintain a high degree of aircraft utilization (i.e., very low NORS rate). Figure 17 is a plot of this data from the simulation outputs, showing the relationship between required spares level and MTBF used for the study. Note that these results apply only to the arbitrary 12-48 hour spares repair time used for the study and are not a true reflection of actual wing spares requirements. Also, these spares quantities reflect total spares by system, and subsystems are not individually identifiable.

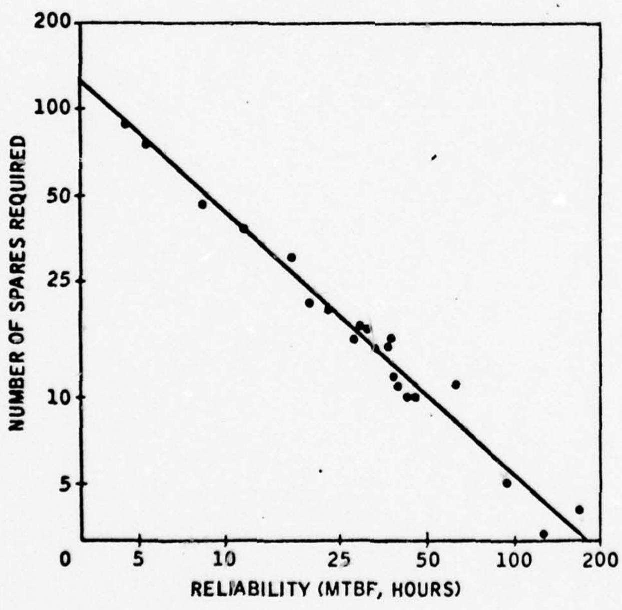

Figure 17. Spares Requirements versus MTBF -- Systems Not Tested by CAPA

Figure 18 illustrates the effect of a CAPA system on the required spares level from the study results, showing the spares required versus MTBF with and without a CAPA system. A CAPA system has two effects on spares level: (1) through an overall increase in reliability of a sensor due to CAPA, fewer maintenance actions are required; (2) As discussed earlier, shop repair time may sometimes be reduced.

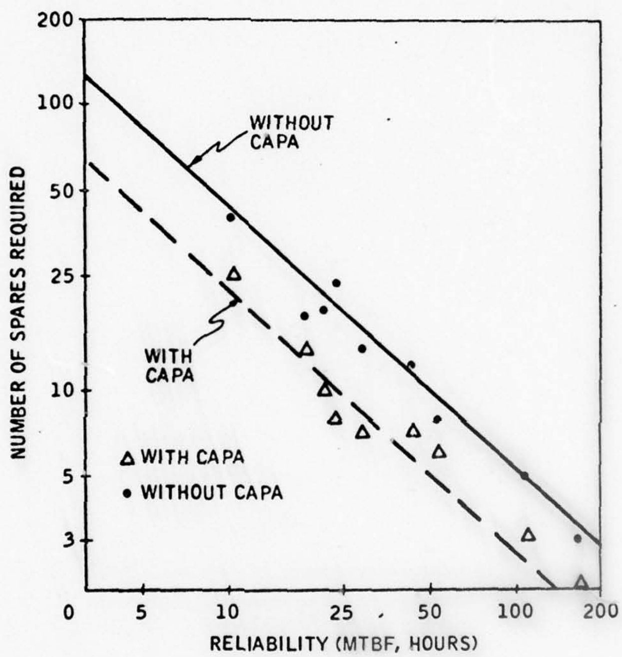

Figure 18. Spares Requirements versus MTBF -- Systems Tested by CAPA

The study results presented in Figure 18 suggest that the effect of the CAPA on a system is to reduce the required line replaceable unit (LRU) spares level by 50 percent.

MISSION EFFECTIVENESS

In the scenario studied, 127 missions per day, consisting of 13 different configurations of sensors, were scheduled for the wing. These configurations of sensors fall into three basic categories:

- Daylight photographic missions
    - a) Low-altitude
    - b) High-altitude
- Night reconnaissance missions
    - a) Photographic and IR
    - b) IR only
- Side-looking radar missions

(ECM or ELINT missions were not considered.)

IN-FLIGHT RELIABILITY

As discussed previously, sensor in-flight reliability is increased due to a CAPA system increasing overall mission effectiveness. Table VIII summarizes mission effectiveness changes due to the CAPA, as determined from the two studies conducted. In determining mission effectiveness, the following assumptions were used:

- Only sensor and sensor control failures were considered (work unit codes 77 and 734). Although the forward-looking radar (FLR), inertial navigation system (INS), and ELRAC influence mission effectiveness and were studied as candidates for testing by the CAPA, their failures were not considered because of the uncertainty regarding their effect on the mission. Hence, the improvement shown due to the CAPA is conservative.
- A mission was considered fully successful if no sensor failure occurred during the mission.
- A mission was considered partially successful if at least one sensor (and control system if applicable) did not fail during the mission.
- A mission was considered a failure if no sensor information was obtained.

From Figure 19 the following conclusions may be drawn:

- The greatest improvement in mission effectiveness due to the CAPA is found during side-looking radar (SLR) missions with an increase in effectiveness of 25 percent between studies 1 (without CAPA) and 2 (with CAPA).

Table VIII. Mission Effectiveness Summary (Study Results)

Description	Night Missions		Daylight Missions		SLR Missions		Composite	
	Study No. 1[a]	Study No. 2[b]	Study No. 1[a]	Study No. 2[b]	Study No. 1[a]	Study No. 2[b]	Study No. 1[a]	Study No. 2[b]
Flights scheduled	138	138	189	189	36	36	363	363
Flights flown	131	135	162	170	35	34	328	339
(%)	(95%)	(98%)	(86%)	(90%)	(97%)	(94%)	(90%)	(93%)
Fully successful	77	89	97	110	12	20	186	219
(%)	(59%)	(66%)	(60%)	(65%)	(34%)	(59%)	(57%)	(65%)
Partially successful	35	32	50	44	-	-	85	76
(%)	(27%)	(24%)	(31%)	(26%)	-	-	(26%)	(22%)
Failure	19	14	15	15	23	14	57	43
(%)	(14%)	(10%)	(9%)	(9%)	(66%)	(41%)	(17%)	(13%)

[a]Without CAPA.

[b]With CAPA on six recon systems.

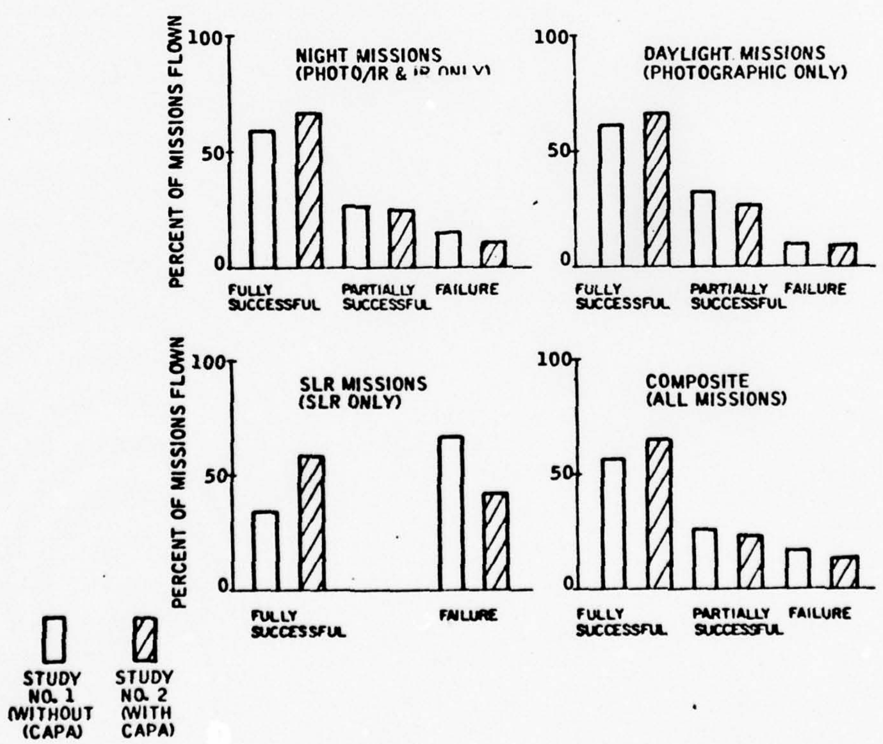

Figure 19. Mission Effectiveness Summary -- CAPA versus Non-CAPA (Study Results)

- The presence of the CAPA during daylight photographic mission increases the percentage of fully successful missions by six to 11 percent, although no decrease in total failure rate was found.

- Night reconnaissance missions experienced both a five- to seven-percent increase in fully successful missions and a one- to four-percent reduction in total failure rate.

- Considering all missions, the percentage of fully successful missions increased from 57 percent without the CAPA to 65 to 66 percent with the CAPA, and the total failure rate dropped from 17 percent to 13 to 14 percent. That is:

  a) Without the CAPA, 83 percent of the reconnaissance missions were partially or fully successful.

  b) With the CAPA on six systems, 87 percent of the missions were partially or fully successful.

Table VIII summarizes the mission effectiveness data presented in Figure 19.

LINE TEST AND SUPPORT EQUIPMENT

The CAPA system serves functionally as an on-board test and checkout system, and its use on a particular sensor or system ideally results in eliminating the need for flight line test equipment, although such equipment is still necessary during periodic inspections. The studies were constructed so that the demand on support equipment generated by maintenance requests could be investigated. The model assumed 10 test sets of each type to be available, so that a delay due to this cause would not occur and confuse other areas of interest. The daily demand for test equipment was evaluated for the two studies conducted, to estimate the minimum number of equipments of each type which would have been required to avoid significant delays. Evaluation results are presented in Table IX. These results are not valid for detailed comparison due to wide day-to-day variations, the elimination of periodic inspection ground support equipment (GSE) requirements, and because insufficient data was available for a good comparison. The data is presented for interest only.

The tentative results presented in Table IX indicate that with a CAPA testing six systems, an 83-percent reduction in flight line test equipment may be possible compared with that required without a CAPA.

Table IX. Maintenance Equipment Requirements

Test Equipment	Number of Test Sets Required	
	Study No. 1[a]	Study No. 2[b]
IR analyzer	1	0
FLR analyzer	3	1
SLR analyzer	4	1
ELRAC analyzer	1	0
Camera analyzer[c]	9	0
INS analyzer	6	2
Total	24	4

[a]Without CAPA.

[b]With CAPA on six recon systems.

[c]Model assumed one needed for each camera maintenance action, without CAPA.

OTHER PARAMETERS

Failures Per Flight

Througnout the studies conducted, an average of 2.2 in-flight failures per flight occurred (all work unit codes). Figure 20 summarizes the number of failures during flight. Note that only eight percent of the flights did not require maintenance action upon landing.

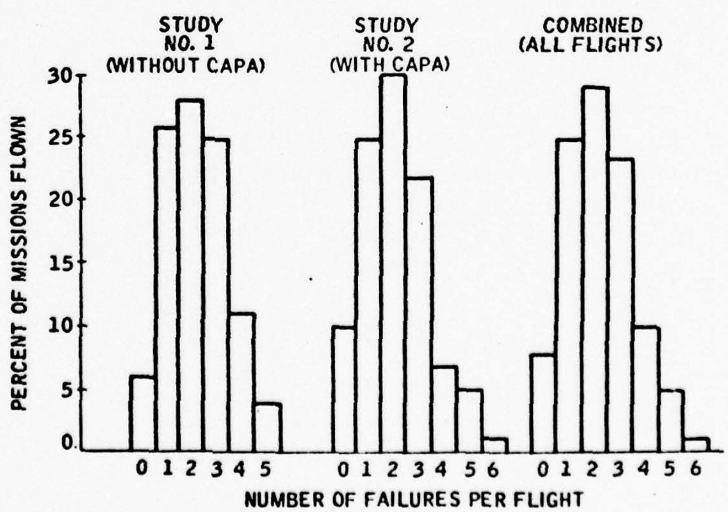

Figure 20. Number of Failures Per Flight

Turnaround Time

One of the primary effects of a CAPA system is that flight line maintenance time is reduced, and aircraft may thus be returned to service more rapidly. In the two studies conducted, the average turnaround time was 11.1 hours and 9.1 hours respectively for studies 1 and 2, thus illustrating how a CAPA system may reduce turnaround time by as much as 18 percent for the RF4C. This turnaround time includes the three hours assumed between aircraft assignment and takeoff, the two-hour assumed flight duration, and the 1.5-hour average scheduled post-flight inspection, as shown in Figure 21.

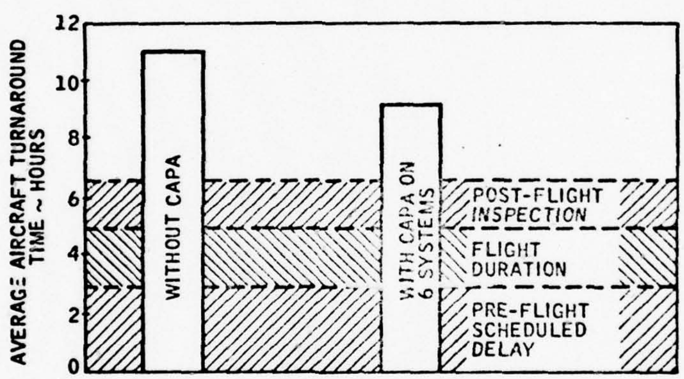

Figure 21. Average Turnaround Time (Study Results)

ECONOMIC BENEFITS

The effect of the operational benefits on the basic economics of RF4C operations was analyzed. This analysis considered eight basic operational benefits that are considered to account for 75 percent of the probable economic impact. Analysis results are shown in Table X.

This analysis considered 60 aircraft wings, shop and flight line maintenance manpower, LRU spares, and flight line aerospace ground equipment (AGE).

Note particularly that the value of the CAPA capability to correctly isolate failures to LRUs in a timely fashion (when they occur) is most evident at the operational flight line level -- i.e., fewer false removals (that in turn

Table X. CAPA Quantified Benefits

Effectiveness Parameter	Annual Dollar Saving Per Aircraft	Operational Improvement
Aircraft availability	$ 37,000	11% more scheduled flights flown
Maintenance skills	8,800	Maintenance men reach required skill level in 6 months rather than 18 months
False LRU removals	79,580	95% reduction
LRU spares	16,700	50% reduction
Mission effectiveness	49,600	16% more successful missions
Support equipment	2,400	1 GSE set less per wing
Deployment	26,900	20% less aircraft and gear to deploy
Attrition	56,400	13% fewer flights over enemy territory
Total	$277,380	---

reflect in savings in spares, support equipment, and deployment costs), increased aircraft availability (aircraft are not down for unnecessary repair), improved mission effectiveness (aircraft are not flown with undetected failures).

It also should be noted that the impact of these savings at the operational flight line level on the balance of the total logistics system were not considered in this economic study.

The basic documentation from which these results were abstracted was based on conservative cost data, and it is our belief that while any detailed claim, figure, or computation may be debatable, the arguments that tend to reduce the economic benefits are no stronger than those that increase the economic benefits. Furthermore, even when considered singly, many of the benefits are large enough to pay for the system in less than two years of operation. When considered in total, the system pays for itself in less than five months of operation. This means that drastic changes in any or all of the economic benefits projected must occur before the CAPA system cannot be justified solely on the basis of economics.

APPENDIX VII

RELIABILITY AND MAINTAINABILITY

During the Central Airborne Performance Analyzer (CAPA) program, the CAPA system logged approximately 2081 hours of operating time. Of this total, 53 hours were operational airborne time, and 2028 hours were spent in functional and compatibility testing on the ground at Shaw Air Force Base, South Carolina, and at Honeywell in Minneapolis.

During these 2081 hours, 31 maintenance actions were required -- 2 during the data gathering phase of the program (Phase I), and 29 during the demonstration Phase (Phase II). This is a remarkable record, especially when one considers that:

1) The CAPA system is an engineering development model. It is not, unlike the systems which it tests, a fully qualified item of production hardware.

2) The CAPA system had logged 2000 to 3000 hours previous to the CAPA program.

3) Of the few failures which occurred during airborne operation, none degraded the performance of the CAPA system to the point where its output was invalidated.

4) Many of the failures occurred during the developmental testing of modifications or additions to the CAPA system.

The imbalance between Phase I and Phase II failures was expected. Phase I was relatively short, not all of the CAPA system was used during that phase, and very little of the modified and additional hardware was operational during that phase.

Of the 31 items repaired, 55 percent were associated with the memory boards. The damage to these boards and their components was due to the large number of times they were removed, changed, and reinserted during the development and debug of the additional Phase II memory. These actions would have been essentially nonexistent had an electrically-alterable memory been used instead of the mechanically-alterable diode memory.

Mechanical stress during servicing and transporting the equipment caused 20 percent of the required repair actions. These consisted of broken or bent connector pins and broken screws.

Another 10 percent of the physically damaged items occurred in the printer where the lateral translation cable broke once, and the detent spring broke and was replaced but later broke again. These failures would be substantially reduced if a military qualified airborne printer were used.

The remaining 15 percent of the maintenance actions were caused by component failures consisting of one capacitor, one reed relay, one zener diode, one power relay, and one oscillator. The latter three items were part of the original Airborne Integrated Maintenance System (AIMS) equipment, which is four years old, and has logged a total of 4000 to 5000 hours with the exception of the memory; this is true of most of the central processor components.

The failures which occurred during Phase II of the program are listed below. The memory problem which occurred during demonstration flights 1 and 2, causing the CAPA to be returned to Minneapolis, is not listed as a failure since the difficulty was caused by an inadequacy in the program rather than a failure.

- Mechanical:

Connectors:	5 damaged connector pins
Cable:	1 broken teflon screw
Printer:	1 lateral control cable failure
Printer:	2 broken detent springs

- Memory:

Diodes:	9 diode failures
Resistors:	1 resistor failure
Shorts:	3 shorts between circuit paths on memory boards
P.C. Board:	4 damaged connector guide slots

- Signal Conditioning:

Capacitors:	1 capacitor failure
Relay:	1 relay failure

- Miscellaneous:

Zener:	1 zener diode failure

APPENDIX VIII
GROUND SOFTWARE

A number of ground computer programs were developed as tools for the criterion and checkout of the in-flight test programs and to aid in the analysis of the data from the flight tests. These programs operated on computers in Minneapolis and to a limited extent in Columbia, South Carolina, near Shaw AFB. The ground software includes:

- Programming aids
- Data analysis programs

PROGRAMMING AIDS

The programming aids were programs used to aid CAPA personnel in the formulation and verification of the CAPA in-flight test programs.

CAPA Assembler

The CAPA assembler transformed a program coded in an English-text symbolic language written by the CAPA programmer into the actual central processor machine language as shown in Figure 22. The assembler also produced a binary map of the machine language which was used as the basis for constructing the diode memory boards for each in-flight program. This binary map is shown in Figure 23.

CAPA Simulator

The CAPA simulator was used to verify that the in-flight programs were correct before the memory boards were constructed. The simulator took the in-flight programs and "simulated" the execution of these programs, including the selection of aircraft system test points, execution of each measurement, and the GO/NO-GO decision based on each measurement result. Provisions within the simulator allowed CAPA personnel to input data for each aircraft test point based on actual flight information. The simulator output listed the contents of each central processor function and control register after every instruction simulation, as shown in Figure 24.

DATA ANALYSIS PROGRAMS

The data analysis programs transformed the information recorded on the CAPA magnetic tape unit into directly usable and understandable formats

```
 CAPA ASSEMBLY                                                  DATE 7  JAN 68
33530  04 0 0217              MPB SV6          3.275,-3.275
33531  25 0 3534              CJP IR24         JUMPS IF TEST GO
33532  04 0 1060              MPB LERROR       IR LRU 2
33533  04 0 1436              MPB STATNG
33534  10 07644          IR24 LSP 4004
33535  04 0 1421              MPB TAPE
33536  10 00050               LSP 40           OFFSET B
33537  04 0 0133              MPB OFFSETA      C23-(-40MV)
33540  10 20 0 00             LSPF 16.0.0      C24/(C23-B)
33541  04 0 0217              MPB SV6          3.275,-3.275
33542  25 0 3552              CJP IR25         JUMPS IF TEST GO
33543  10 00050               LSP 40           OFFSET B
33544  04 0 0133              MPB OFFSETA      C23-(-40MV)
33545  10 20 0 00             LSPF 16.0.0      C24/(C23-B)
33546  04 0 0217              MPB SV6          3.275,-3.275
33547  25 0 3552              CJP IR25         JUMPS IF TEST GO
33550  04 0 1060              MPB LERROR       IR LRU 2
33551  04 0 1436              MPB STATNG
33552  01 0 05 54        IR25 STP 5.44         C13.C131
33553  10 07646               LSP 4006
33554  04 0 1421              MPB TAPE
33555  00043132               SRU 12.1.13.0    RU12 ODD TO  B.RU13 EVEN TO A
33556  04 0 1010              MPB CHARCL       FLAG NO PRINT
33557  10 20 0 00             LSPF 16.0.0      DC MEAS V/A
33560  04 0 0512              MPB SV87         -.100,.100
33561  25 0 3602              CJP IR3          JUMPS IF V/H NOT GREATER THAN 150 MV
33562  04 0 1071              MPB OERROR       IR LRU 4
33563  10 01072               LSP 570          OFFSET B
33564  04 0 0133              MPB OFFSETA      (C13-570) TO RATIO DACON
33565  10 20 0 00             LSPF 16.0.0      C308/(C13-570)
33566  04 0 0515              MPB SV88         -3.275,3.275
33567  01 0 05 33             STP 5.27         C24A
33570  00043231               SRU 13.0.12.1
33571  04 0 1071              MPB OERROR       IR LRU 4
33572  04 0 1010              MPB CHARCL
33573  10 00 0 02             LSPF 00.0.2      DC RATIO C24/C308
33574  04 0 0523              MPB SV90
33575  00043132               SRU 12.1.13.0
33576  04 0 1060              MPB LERROR
33577  04 0 1010              MPB CHARCL
33600  10 00 0 02             LSPF 00.0.2      DC RATIO C308/C24
33601  04 0 0526              MPB SV91
33602  01 0 05 36         IR3 STP 5.30         C9D.C30D
33603  10 07650               LSP 4006
33604  04 0 1421              MPB TAPE
33605  04 0 1052              MPB JERROR       IR READY
33606  00043332               SRU 13.1.13.0    RU13 ODD TO B.RU13 EVEN TO A
33607  10 20 0 00             LSPF 16.0.0      DC MEAS C300
33610  04 0 0531              MPB SV92         2.75,2.2
33611  01 0 05 52             STP 5.42         C15.C16
33612  04 0 1010              MPB CHARCL       FLAG NO PRINT
33613  10 00 0 00             LSPF 00.0.0      DC MEAS C15
33614  04 0 0405              MPB SV58         .010,.200
33615  25 0 3626              CJP IR5          JUMPS IF C15 IN LIMITS
33616  10 20 0 00             LSPF 16.0.0      DC MEAS C16
```

Figure 22. CAPA Central Processor Machine Language

CAPA ASSEMBLY DATE 7 JAN 68 PAGE 0070

03513	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
03514	0	0	1	0	0	0	0	0	0	1	0	1	0	1	1	0	0	1
03515	1	0	1	0	1	0	0	1	1	1	1	0	0	0	0	0	1	0
03516	0	0	0	0	1	0	0	0	0	1	0	1	1	0	1	0	1	1
03517	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
03520	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
03521	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1
03522	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03523	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1
03524	1	0	1	0	1	0	0	1	1	1	0	1	0	1	1	1	0	0
03525	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
03526	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1
03527	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03530	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1
03531	1	0	1	0	1	0	0	1	1	1	0	1	0	1	1	1	0	0
03532	0	0	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0
03533	0	0	1	0	0	0	0	0	1	1	0	0	0	1	1	1	1	0
03534	0	1	0	0	0	0	1	1	1	1	1	0	1	0	0	1	0	0
03535	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1
03536	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
03537	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1
03540	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
03541	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1
03542	1	0	1	0	1	0	0	1	1	1	0	1	1	0	1	0	1	0
03543	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
03544	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1
03545	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
03546	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1

Figure 23. Machine Language Binary Map

```
CAPA ASSEMBLY                                                          DATE 3  JAN 68

INST TIME    SEQ.    ACC    CACAN    RDCN    SP1     SP2     SP3     SP4     SP5     SP6     MPR     TFC

PRINTOUT SUPPRESSED FOR REMAINDER OF SKS LOOP

 RTN 14724  .2212                 .4427   .7777                                        014452  003326  002212  000000
 REMOTE UNITS:  (   .  1).  1(  .  1).  2(  .  1).  3(  .  1).  4(  .  1).  5(  .  1).  6(  0.  1).  7(  0.  1).
 CHANNEL A:  7. DE     CHANNEL B:  7. EV       CHANNEL A TO DECISION AMPLIFIER       IMM

 RRR 14732   .2217               .4427   .7777                                         014452  003326  002215  000000
 REMOTE UNITS:  (   .  1).  1(  .  1).  2(  .  1).  2(  .  1).  4(  .  1).  5(  0.  1).  6(  0.  1).  7(  0.  1).
 CHANNEL A:  4. EV     CHANNEL B:  4. RD       CHANNEL A TO DECISION AMPLIFIER       IMM

PRINTOUT SUPPRESSED FOR REMAINDER OF SKS LOOP

PRINTOUT SUPPRESSED FOR REMAINDER OF SKS LOOP

 RTN 14648  002216  000000  004511  007777  000000  000200  000000  000000  005101  004507  002216  000000
 REMOTE UNITS:  (  .  1).  1(  0.  1).  2(  0.  1).  3(  0.  1).  4(  0.  1).  5(  0.  1).  6(  0.  1).  7(  0.  1).
 CHANNEL A:  4. EV     CHANNEL B:  4. RD       CHANNEL A TO DECISION AMPLIFIER       IMM

 RRR 14654  002203  000000  004511  007777  010000  000200  000000  000000  005101  004507  002220  000000
 REMOTE UNITS:  (  .  1).  1(  0.  1).  2(  .  1).  3(  0.  1).  4(  0.  1).  5(  0.  1).  6(  0.  1).  7(  0.  1).
 CHANNEL A:  4. EV     CHANNEL B:  4. RD       CHANNEL A TO DECISION AMPLIFIER       IMM

PRINTOUT SUPPRESSED FOR REMAINDER OF SKS LOOP

 RTN 14653  .2220                 .4511   .7777                                005111  004507  002220  000000
 REMOTE UNITS:  (  .  1).  1(  0.  1).  2(  .  1).  3(  0.  1).  4(  0.  1).  5(  0.  1).  6(  0.  1).  7(  0.  1).
 CHANNEL A:  4. EV     CHANNEL B:  2. RD       CHANNEL B TO DECISION AMPLIFIER       IMM

 RRR 14664  .2224                 .4511   .7777                                005101  004507  002221  000000
 REMOTE UNITS:  (  0.  1).  1(  0.  1).  2(  .  1).  3(  0.  1).  4(  0.  1).  5(  0.  1).  6(  0.  1).  7(  0.  1).
 CHANNEL A:  4. EV     CHANNEL B:  4. RD       CHANNEL B TO DECISION AMPLIFIER       IMM

 RTN 14661  .2221                 .4511   .7777                                005101  000000  002221  000000
 REMOTE UNITS:  (  0.  1).  1(  0.  1).  2(  .  1).  3(  0.  1).  4(  0.  1).  5(  0.  1).  6(  0.  1).  7(  0.  1).
 CHANNEL A:  4. EV     CHANNEL B:  1. RD       CHANNEL B TO DECISION AMPLIFIER       IMM

 RRR 14662  .   .                 .4511   .7777                                005101  000000  002222  000000
 REMOTE UNITS:  (  .  1).  1(  0.  1).  2(  .  1).  3(  0.  1).  4(  0.  1).  5(  0.  1).  6(  0.  1).  7(  0.  1).
 CHANNEL A:  4. EV     CHANNEL B:  4. RD       CHANNEL B TO DECISION AMPLIFIER       IMM

 RTN 14667  .2222                 .4511   .7777                                005101  000000  002222  000000
 REMOTE UNITS:  (  0.  1).  1(  0.  1).  2(  0.  1).  3(  0.  1).  4(  0.  1).  5(  0.  1).  6(  0.  1).  7(  0.  1).
 CHANNEL A:  4. EV     CHANNEL B:  1. RD       CHANNEL B TO DECISION AMPLIFIER       IMM
```

Figure 24. CAPA Mode 7 GO Simulator Output

data analysis by CAPA personnel. The specific data analysis pro-
ms associated with each CAPA project phase are discussed below.

a Gathering Phase I

ese data analysis programs described below exhibited the characteristics each aircraft system test point and therefore were useful in determining GO/NO-GO criteria for each test point:

- Octal Tape Dump -- This program provided a binary "mirror image" printout of the magnetic tape for verifying correct recording format.

- Decimal Printout -- Each test point result was converted to a decimal format and listed as shown in Figure 25. The relative position of each data value was used to correlate each aircraft test point and its test result.

- Statistical Printout -- A statistical analysis of each test point result for any selected length of time during a flight included:

    1) Minimum value encountered

    2) Maximum value encountered

    3) Arithmetic mean of all points

    4) Standard deviation

    5) Number of measurements included in the analysis

  This output is shown in Figure 26. It was useful for determining the limits for predominantly repetitive test results.

- Time Plot -- Any test point or group of test points was plotted versus time as shown in Figure 27. This graphical format was useful in locating the occurrence of unusual or discrete events.

- X-Y Plots -- A graphical plot of one test point versus another illustrated relationships, if any, between two test points, as shown in Figures 28, 29, and 30. These plots were used to formulate specific equations incorporated during the demonstration Phase II in-flight program.

TEST 1

179 VALID WORDS

	CAPA T.P. AC REF.	CAPA T.P. AC REF POM = 2500 nominal (400 Hz)							MODE 5	MODE 1	MODE 7	MODE 6	CAPA T.P. 5LC GRD.	CAPA T.P. LF. RU. DC		
	3730	2476	-6	2314	2420	-2284	54	30	42	32	52	312	-8	2654	1782	
	2726	2506	2574	2414	-2454	2678	372	2	-1560	2498	-1412	-1408	-450	-196	838	(30)
	-130	0	1896	1896	12	0	10	0	14	1266	0	-1482	-836	260	278	
	-202	-90	-8	22	-8	-2	-4	4	32	10	-10	1042	MODE 4 -16	MODE 3 54	352	(60)
	68	-4	26	38	548	42	516	28	50	40	-154	194	-6	-56	54	
MODE 2	-370	-498	150	-1646	542	162	-4	1058	-212	256	-212	-92	182	34	30	(90)
	986	2476	994	0	-1612	678	2050	2186	2	2 n. REF	2 LF. RU. DC	2	2	0	0	
	2	672	50	622	44	126	-82	46	12	-8	2542	1622	4092	2556	2346	(120)
	2506	2474	2438	2452	-234	-140	-2108	870	2494	436	2558	2454	-14	2488	184	
	-394	188	-390	44	-30	-706	-58	46	-2	-14	16	2414	2426	0	1266	(150)
	446	-46	2	2	2	2	528	1266	854	1234	44	62	688	1446	0	
	374	-386	338	-264	292	-490	240	442	296	2438	404	2	104	2462		
														(179)		

179 VALID WORDS

	3740	2464	-6	2310	2418	-2290	50	42	38	34	62	492	-10	2650	1708
	2716	2502	2558	2374	-2450	2578	374	2	-1560	2498	-1416	-1410	-450	-196	838
(31)	-130	0	1994	1894	78	0	534	0	14	1262	0	-1482	-834	262	280
	-206	-90	-6	-22	-6	-2	-6	2	46	114	-10	1042	-10	38	374
(61)	80	-6	28	46	678	48	636	-94	-146	-18	-22	186	-4	-34	62
	-462	-638	182	-1616	558	188	-10	1066	-214	214	-210	-110	142	0	20
(91)	974	2418	1002	0	-1618	570	2046	2186	2	2	2	2	2	0	0
	2	794	62	782	46	166	18	46	10	-6	2546	1622	4088	2614	2402
(121)	2482	2452	2520	2522	-22	-174	-2112	866	2494	438	2556	2450	-12	2490	192
	-546	200	-536	42	-26	-100	-50	26	-2	-8	24	2420	2432	0	1266
(151)	450	-60	2	2	2	2	528	1266	866	1248	-66	80	694	1430	0
(166)	190	-304	290	-230	306	-594	276	258	296	2436	402	0	104	2490	

138 VALID WORDS

3742	2480	-6	2316	2422	-2290	52	38	34	34	64	716	-8	2658	1692
2702	2502	2566	2398	-2522	2592	362	6	-1862	2422	-1638	-1634	-448	-194	846
-126	0	1890	1890	712	0	8	0	10	1260	0	-1478	-828	256	280
-214	-86	-6	102	-8	-2	-4	4	50	46	-10	1038	-8	42	796
68	-8	22	44	658	30	604	-58	-84	86	-4	166	-4	14	48
-570	-754	190	-1612	564	198	-6	1080	-204	284	-206	-58	160	38	20
978	2392	096	0	-1616	574	2050	2182	2	2	444	2324	470	0	0
2	322	20	282	46	34	-130	150	74	-8	2556	1602	4072	2558	2390
2518	2404	2502	2484	68	-132	-2116	868	2504	436	2562	2454	-14	2488	198
-606	178	62												

Figure 25. Decimal Printout -- Flight No. 2, Run No. 4

CAPA DATA WORD NO — number of data points included in analysis

TEST	TEST POINT	N	MEAN	STD DEV	MAX	MIN	TEST POINT	N	MEAN	STD DEV	MAX	MIN
1	C32 1	60	3736.4	7.40	3772	3718	C33 2	60	2479.8	9.82	2520	2462
1	C43 3	60	-5.9	4.15	20	-10	C46 4	60	2315.9	4.00	2326	2310
1	C47 5	60	2417.9	3.39	2426	2410	C48 6	60	-2285.9	1.80	-2284	-2290
1	C104 7	60	60.1	13.19	126	38	C113 8	60	35.4	35.21	172	-92
1	C101 9	60	41.2	73.63	328	-252	C109 10	60	3.1	1030.61	3742	-3720
1	C102 11	60	42.2	18.07	86	-52	C111 12	60	-2.2	177.15	492	-864
1	SLR CAL 13	60	-8.1	2.97	0	-18	LRU DC 14	60	2652.2	13.04	2670	2602
1	~~AC REF~~ 15	~~60~~	~~1714.5~~	~~[illegible]~~	~~[illegible]~~	1632	~~NO DATA~~ 16	60	2719.4	14.65	2736	2648
1	AC REF 17	60	2501.4	1.97	2508	2496	C41 18	60	2565.7	4.43	2574	2558
1	C31 19	60	2404.4	12.32	2430	2374	C49 20	60	-2457.9	22.39	-2442	-2528
1	C42 21	60	2579.4	3.67	2594	2574	C45 22	60	367.2	5.13	378	356
1	C44 23	60	2.6	2.46	16	-6	C38 24	60	-1588.5	74.94	-1546	-1846
1	C34 25	60	2475.8	25.05	2502	2408	C40 26	60	-1447.9	56.92	-1406	-1642
1	C39 27	60	-1443.7	57.43	-1402	-1640	C37 28	60	-452.3	4.88	-442	-468
1	C36 29	60	-196.6	3.45	-192	-206	C50 30	60	853.3	12.21	878	830
1	C35 31	60	-130.8	5.38	-124	-154	C54 32	60	.0	.00	0	0
1	C52 33	60	1859.6	26.41	1918	1822	C52 34	60	1859.7	26.60	1918	1822
1	C551 35	60	248.6	484.38	2500	8	C54/C53 36	60	.0	.00	0	0
1	C53 37	60	38.6	80.23	534	6.	C55 38	60	.0	.00	0	0
1	C57 39	60	45.1	116.01	840	8	C63 40	60	1203.1	190.88	1280	146
1	C59 41	60	.0	.00	0	0	C61 42	60	-1500.9	16.72	-1468	-1526
1	C60 43	60	-851.4	17.42	-810	-870	C64 44	60	263.4	3.71	274	254
1	C62 45	60	282.7	3.97	294	274	C66 46	60	-223.8	11.56	-202	-248
1	C65 47	60	-99.9	11.80	-80	-122	C55 48	60	-4.9	7.82	32	-10
1	C104 49	60	25.7	39.93	146	-48	C61 50	60	-7.9	3.69	-4	-34
1	C68 51	60	-12.8	13.68	2	-54	C70 52	60	-4.6	1.42	0	-6
1	C69 53	60	3.9	1.36	6	2	C87 54	60	12.1	17.48	64	-20
1	C88 55	60	3.3	87.67	198	-268	C108 56	60	-10.3	2.88	-4	-18
1	C80 57	60	1038.4	2.93	1044	1030	C110 58	60	7.7	1045.37	3730	-3614
1	C101 59	60	55.3	71.14	364	-204	C112 60	60	10.5	177.79	574	-786
1	C102 61	60	51.5	17.83	100	-26	C114 62	60	-8.9	18.42	118	-36
1	C103 63	60	23.8	7.77	48	-6	C87 64	60	13.6	16.33	58	-18
1	C78 65	60	137.7	268.83	892	-342	C85 66	60	-11.5	28.73	54	-100
1	C78 67	60	149.4	262.27	852	-276	C88 68	60	-1.2	81.15	192	-292
1	C77 69	60	.8	129.25	322	-462	C86 70	60	9.1	78.21	236	-160
1	C77 71	60	-2.5	134.46	262	-396	C84 72	60	179.0	39.01	264	94
1	C82 73	60	-5.3	3.84	4	-14	C86 74	60	-16.3	81.11	224	-230
1	C85 75	60	1.1	30.11	62	-90	C90 76	60	-796.3	1186.76	894	-3586
1	C89 77	60	205.5	872.09	2482	-740	C71 78	60	174.4	25.63	210	104
1	C73 79	60	-1624.4	29.53	-1602	-1714	C72 80	60	570.8	35.10	664	504
1	C71 81	60	181.7	21.44	210	116	C91 82	60	-6.0	2.10	-4	-20
1	C79 83	60	1073.2	8.26	1080	1032	C92 84	60	-204.1	21.44	-162	-238
1	C106 85	60	247.3	22.49	282	206	C92 86	60	-204.5	21.26	-162	-238
1	C106 87	60	23.1	126.19	268	-144	C83 88	60	125.6	65.02	232	-24
1	C81 89	60	26.6	24.04	[illegible]	[illegible]	C107 90	60	20.5	[illegible]	[illegible]	-36
1	C105 91	60	975.9	16.16	988	914	C100 92	60	1959.0	333.16	2518	1316
1	C99 93	60	1012.6	10.51	1030	990	C100 94	60	.0	.00	0	0
1	C74 95	60	-1630.5	19.56	-1610	-1692	C72 96	60	582.2	33.89	684	524
1	C116 97	60	2061.0	212.35	2846	1666	C115 98	60	2163.5	173.25	2488	1542
1	C97/C95 99	60	2.0	.00	2	2	C98/C96 100	60	2.0	.00	2	2
1	591/511 101	60	87.0	291.83	460	-1640	591/521 102	60	615.4	1017.48	2380	2
1	591/931 103	60	136.7	206.33	484	2	59/931 104	60	.0	.00	0	0
1	59/941 105	60	.0	.00	0	0	591/941 106	60	2.0	.00	2	2
1	C76 107	60	-161.7	490.92	794	-1636	C85 108	60	-1.3	28.68	64	-90
1	C76 109	60	-168.6	492.56	782	-1648	C87 110	60	18.0	17.22	70	-12
1	C75 111	60	30.7	136.03	454	-366	C88 112	60	6.1	92.33	240	-244
1	C75 113	60	24.7	137.92	460	-252	C86 114	60	3.2	82.94	266	-180
~~1~~	~~AC REF~~ 115	60	-0.1	1.89	-4	-14	RRU DC 116	60	2551.9	5.37	2566	2540
1	C5B 117	60	1617.2	17.15	1654	1548	C4 118	60	809.3	4003.54	4092	-4094
1	C5A 119	60	2595.3	19.90	2636	2550	C3 120	60	2387.5	20.72	2432	2346
1	C1A 121	60	2511.3	26.37	2576	2458	C2 122	60	2425.7	31.96	2488	2374
1	C1C 123	60	2505.3	20.80	2552	2438	C1B 124	60	2498.3	18.73	2550	2452
1	C4B 125	60	-3.4	160.82	214	-250	C14 126	60	-175.8	33.57	-130	-298
1	C6A 127	60	-2114.5	7.62	-2102	-2134	C7 128	60	868.5	2.54	879	864
1	C9A 129	60	2500.6	5.32	2510	2492	C8 130	60	439.2	2.55	446	434
1	C9C 131	60	2560.3	2.98	2570	2556	C9B 132	60	2453.2	3.49	2470	2444
1	C30D 133	60	-11.8	4.23	4	-24	C9D 134	60	2491.2	3.50	2502	2484
1	C28 135	60	146.5	15.44	192	100	C11 136	60	174.4	215.37	874	-546
1	C28 137	60	149.7	21.13	200	102	C11 138	60	-46.5	202.87	364	-770
1	C12 139	60	35.6	7.20	56	20	C17 140	60	-30.6	8.77	-10	-46
1	C12 141	60	-42.7	51.48	62	-114	C17 142	60	4.8	41.19	90	-64
1	C10 143	60	27.3	86.38	210	-354	C29 144	60	7.7	341.64	1240	-1832
1	C10 145	60	-24.6	95.40	150	-374	C29 146	60	20.7	248.31	1686	-606
1	C2E 147	60	2444.8	42.24	2486	2402	C20 148	60	2457.6	22.32	2498	2414
1	3CA3CA1 149	60	.4	.82	2	0	C30A 150	60	1266.0	.68	1268	1264
1	C27 151	60	230.5	403.96	458	-550	C26 152	60	-36.9	241.82	472	-282
1	3CC/26 153	60	8.1	26.62	130	2	3CC/26 154	60	4.2	16.64	132	2
1	3CC/26 155	60	4.0	15.62	124	2	3CC/25 156	60	2.0	.00	2	2
1	3CC/25 157	60	502.2	114.83	560	2	C25 158	60	1266.0	.68	1268	1264
1	C7 159	60	865.9	2.33	870	858	C30A 160	60	1239.8	18.30	1254	1126
1	C16 161	60	-87.4	90.21	70	-236	C15 162	60	43.9	29.80	112	2
1	C16 163	60	605.7	241.26	1054	212	C15 164	60	1554.1	269.62	2026	1070
1	13/131 165	60	.0	.00	0	0	C24 166	60	104.9	444.69	754	-916
1	C23 167	60	-114.9	430.82	844	-906	C24 168	60	276.6	227.79	918	-474
1	C23 169	60	-215.3	242.46	548	-946	C30B 170	60	300.0	48.42	436	230
1	C24 171	60	-510.3	288.14	650	-1252	C30B 172	60	300.8	43.04	446	238
1	C24 173	60	259.3	241.75	910	-446	C30B 174	60	307.7	44.20	446	218
1	C19 175	60	2437.0	1.88	2442	2432	C30B 176	60	347.3	87.30	544	22
1	C18 177	60	1.1	2.17	6	-4	K572F 178	60	24.6	36.41	104	-58
1	K572R 179	60	2420.3	57.82	2530	2102						

Figure 26. CAPA Data Analysis Program

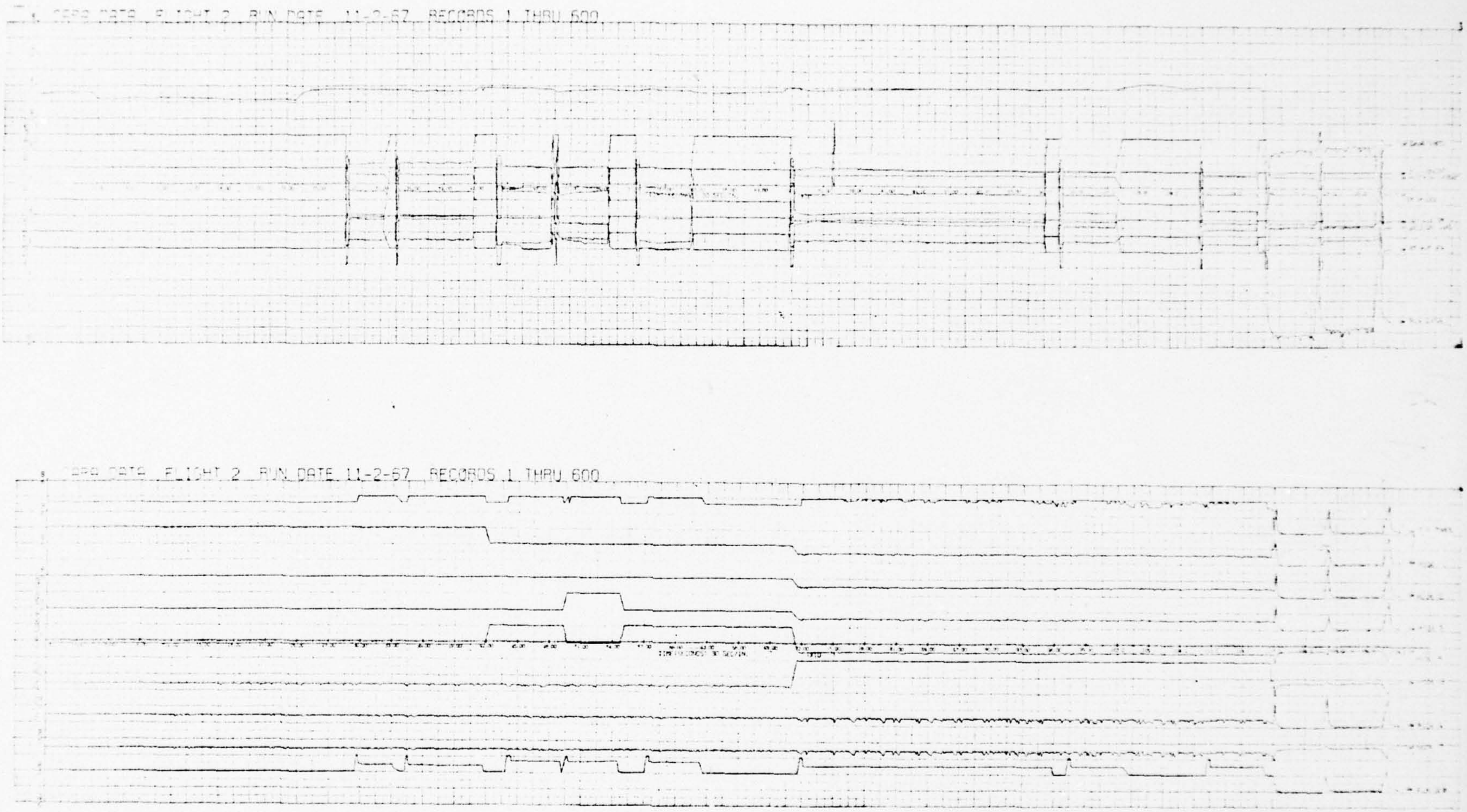

Figure 27. Time Plot -- Test Points versus Time

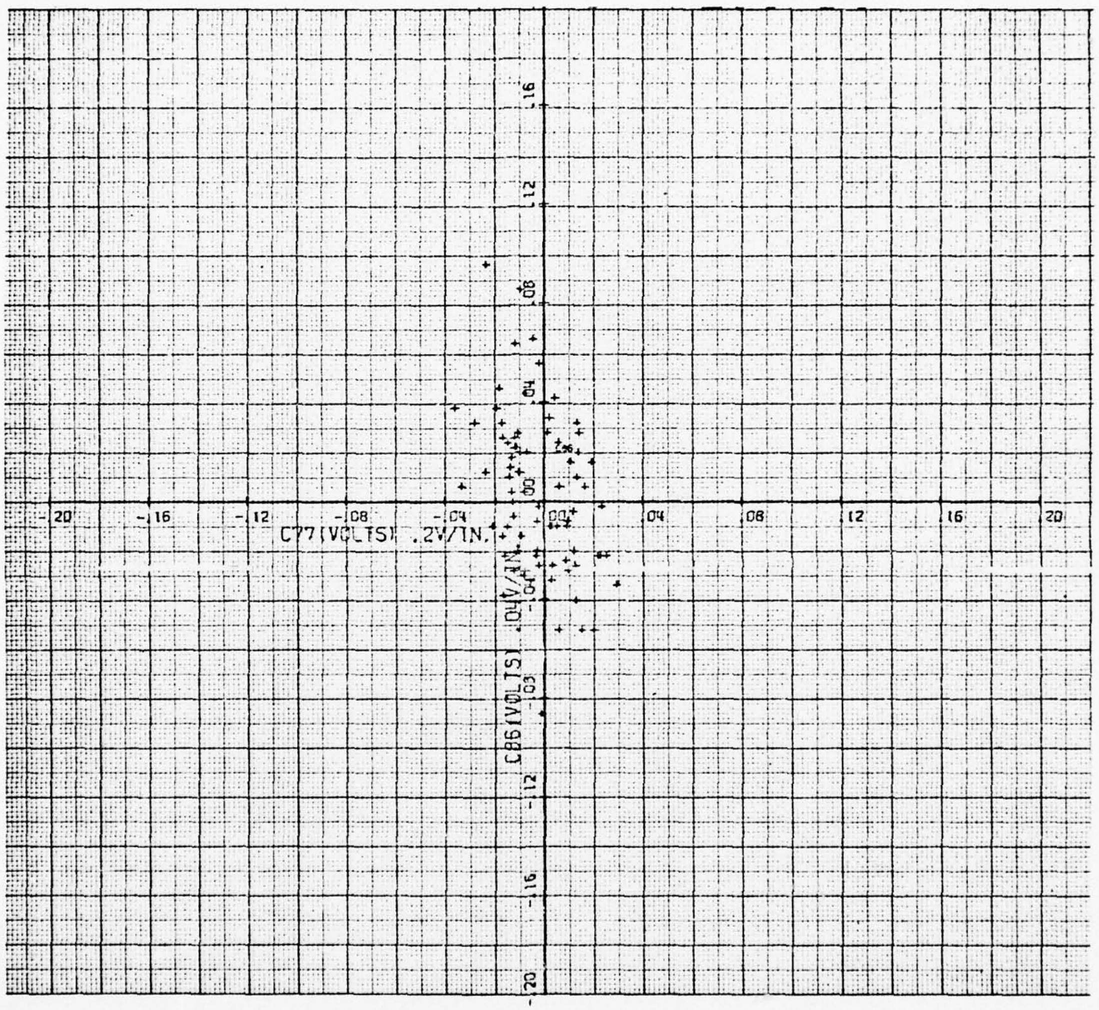

Figure 28. CAPA Data X-Y Plot -- Flight 6

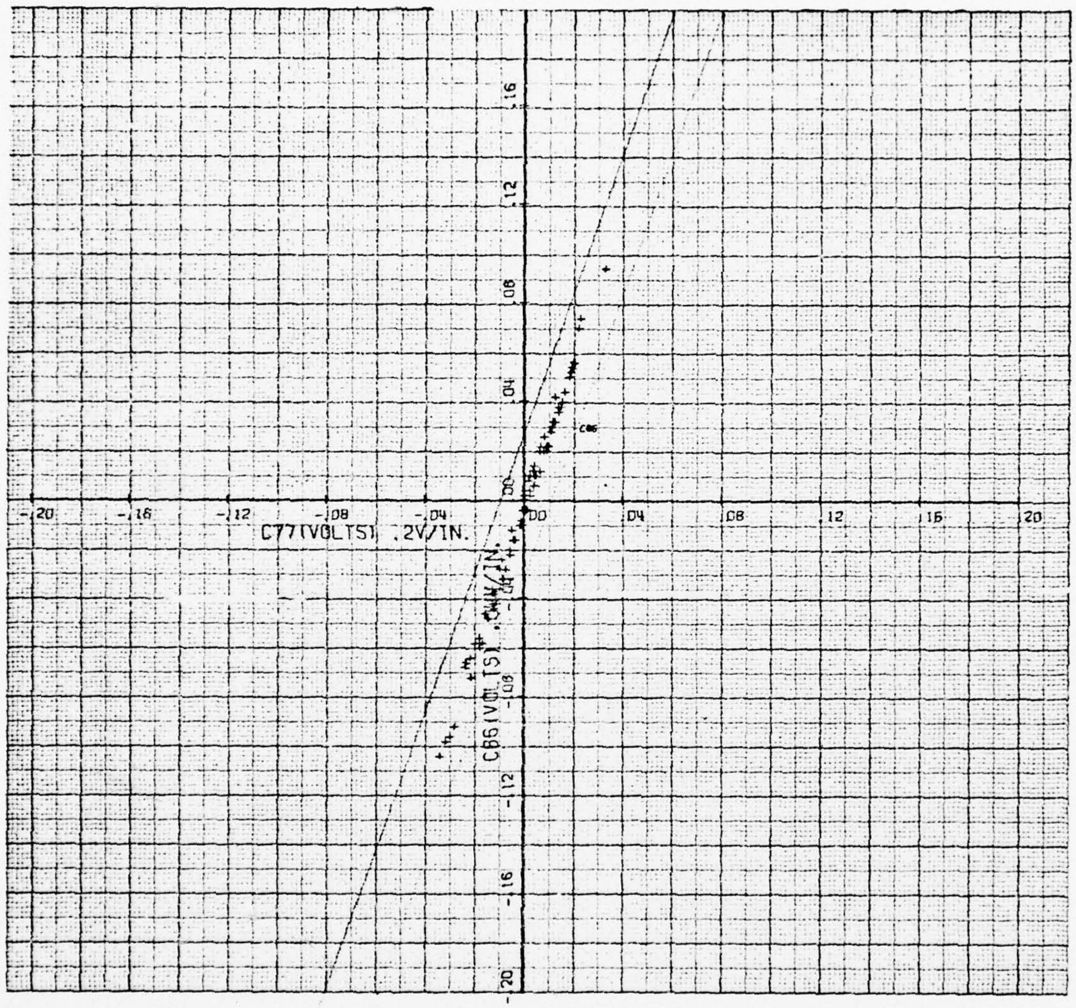

Figure 29. CAPA Data X-Y Plot -- Flight 6.

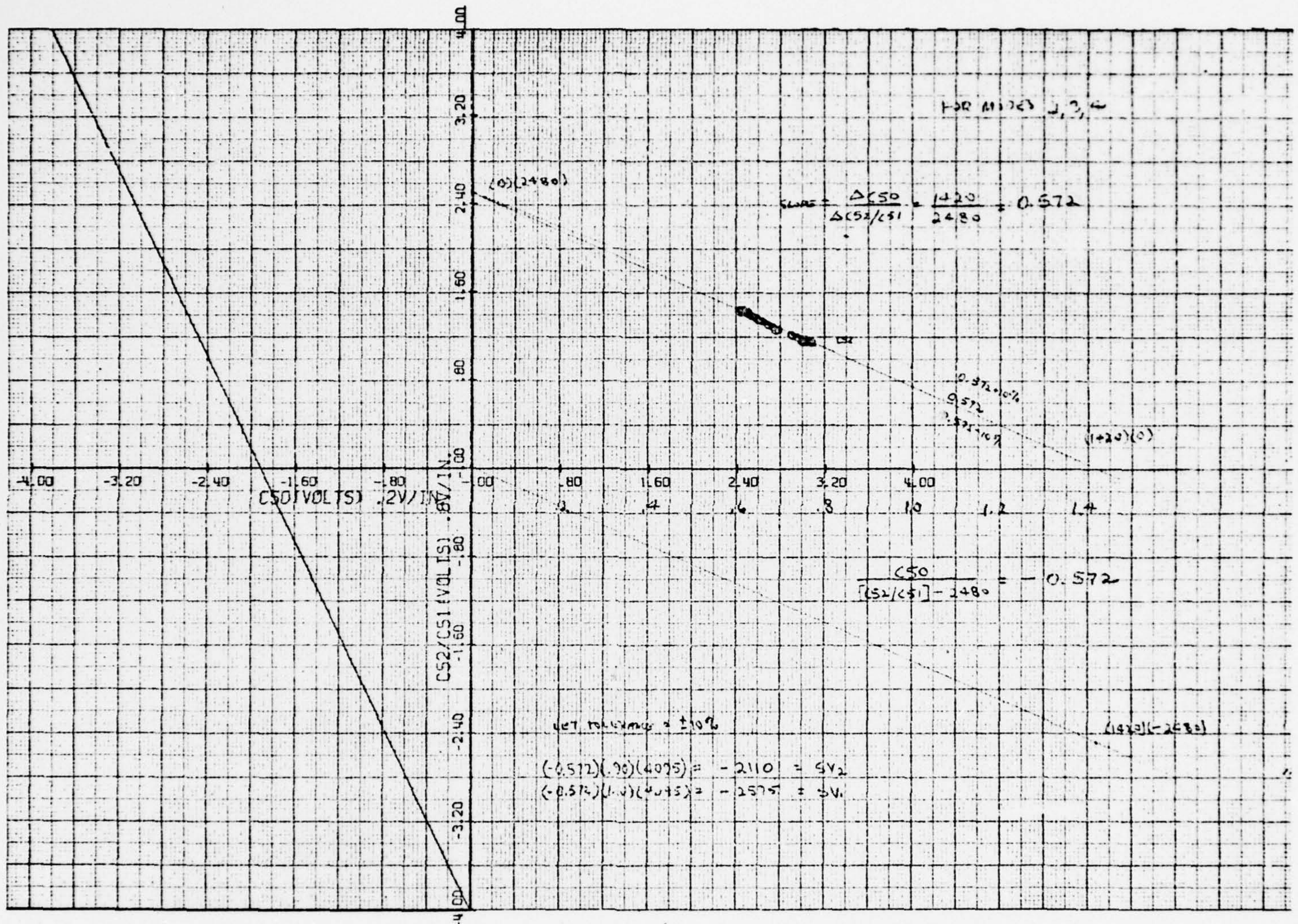

Figure 30. CAPA Data X-Y Plot -- Flight 6, Run 2

Demonstration Phase II

These data analysis programs were used to investigate and verify the decisions and maintenance messages produced by the demonstration Phase II in-flight program. The following programs, functionally identical to the Phase I data analysis programs, were used during the demonstration Phase II data analysis:

- Octal Dumps
- Decimal Printout -- This program was updated to include the option of producing a condensed printout of only that data responsible for each CAPA in-flight printer message.
- Statistical Printout
- Time Plot

A Statistical Long-Term Plot program was developed to enhance the Phase II analysis. The following statistical outputs of any aircraft test point for a five-minute time block could be plotted:

- Maximum value encountered
- Minimum value encountered
- Arithmetic mean

This program enabled a single test point parameter from all demonstration Phase II test flights to be plotted on a single graph, as shown in Figure 31. This plot was useful in viewing the history of any test point during the demonstration Phase II.

An illustrative example of a monitored test point is included in this section to demonstrate the visibility which can be obtained by plotting on graph paper the information accummulated by the in-flight recording. The selected test point is C2; it is the signal obtained from the IR regulated +2.5-volt d-c power supply.

The normal voltage appears on Figure 32 for flight 8. Each small division of the vertical scale represents 50 millivolts, so the excursions on the graph represent a maximum deviation of 75 millivolts from the nominal +2.5 volts. Figure 33 shows C2 during flight 8A; the excursions of up to 300 millivolts from normal indicate at least some degradation in signal, although at this point no noticeable degradation in the film had occurred. During flight 10, shown in Figure 34, deviations of more than 1000 millivolts from normal occurred. The photointerpreter's report for this flight described the IR film as "imagery is very washed out and is poor quality". The result of the failure in flight 10 can be plainly seen in flight 11 in Figure 35; the nominal value has been shifted from +2.5 volts to some

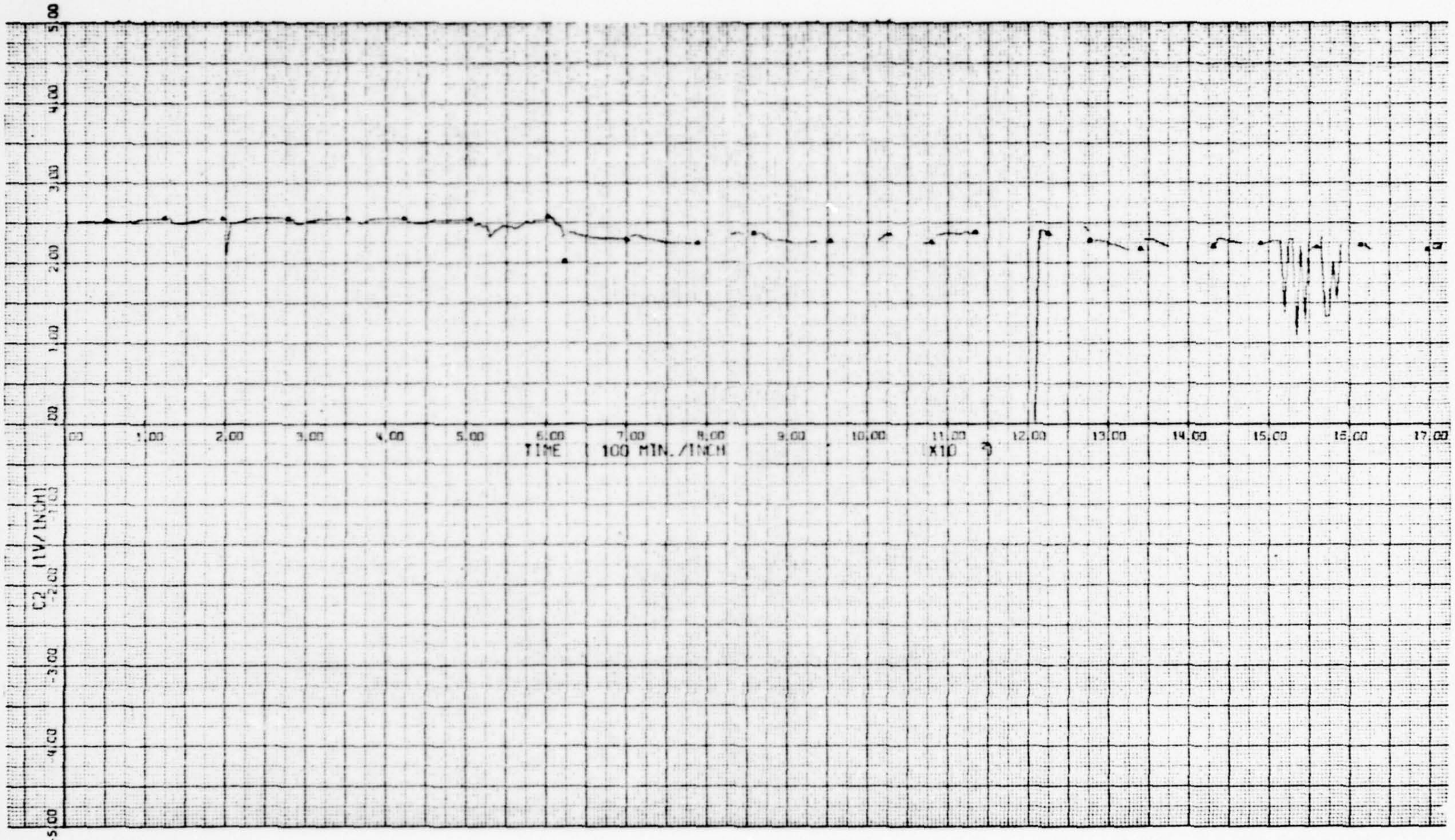

Figure 31. CAPA File Plots -- Flights 3 through 26

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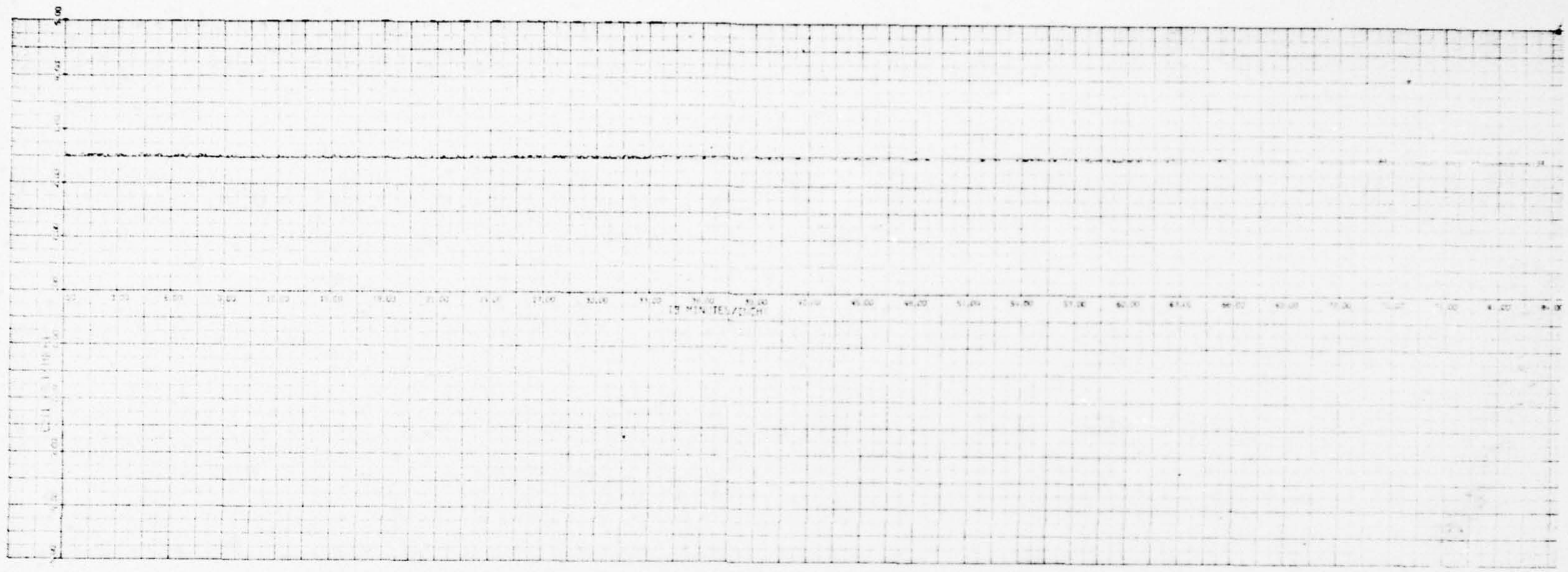

Figure 32. CAPA Data Flight 8 -- Time 0 through 82.2

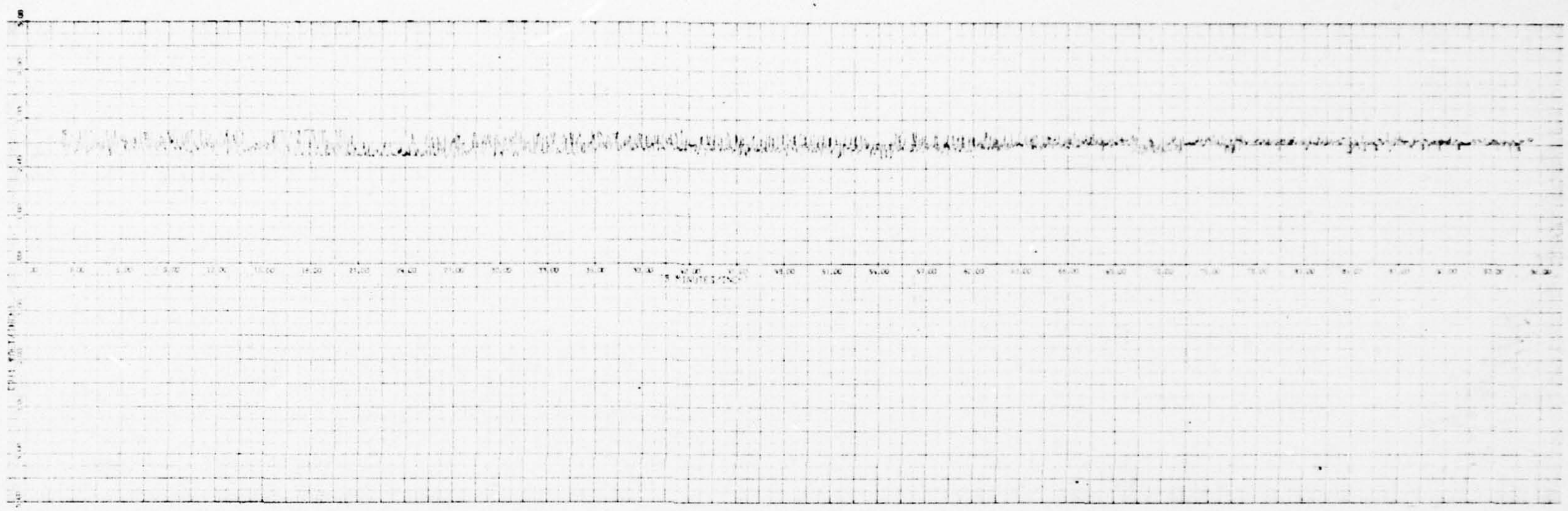

Figure 33. CAPA Data Flight 8A -- Time 0 through 96.7

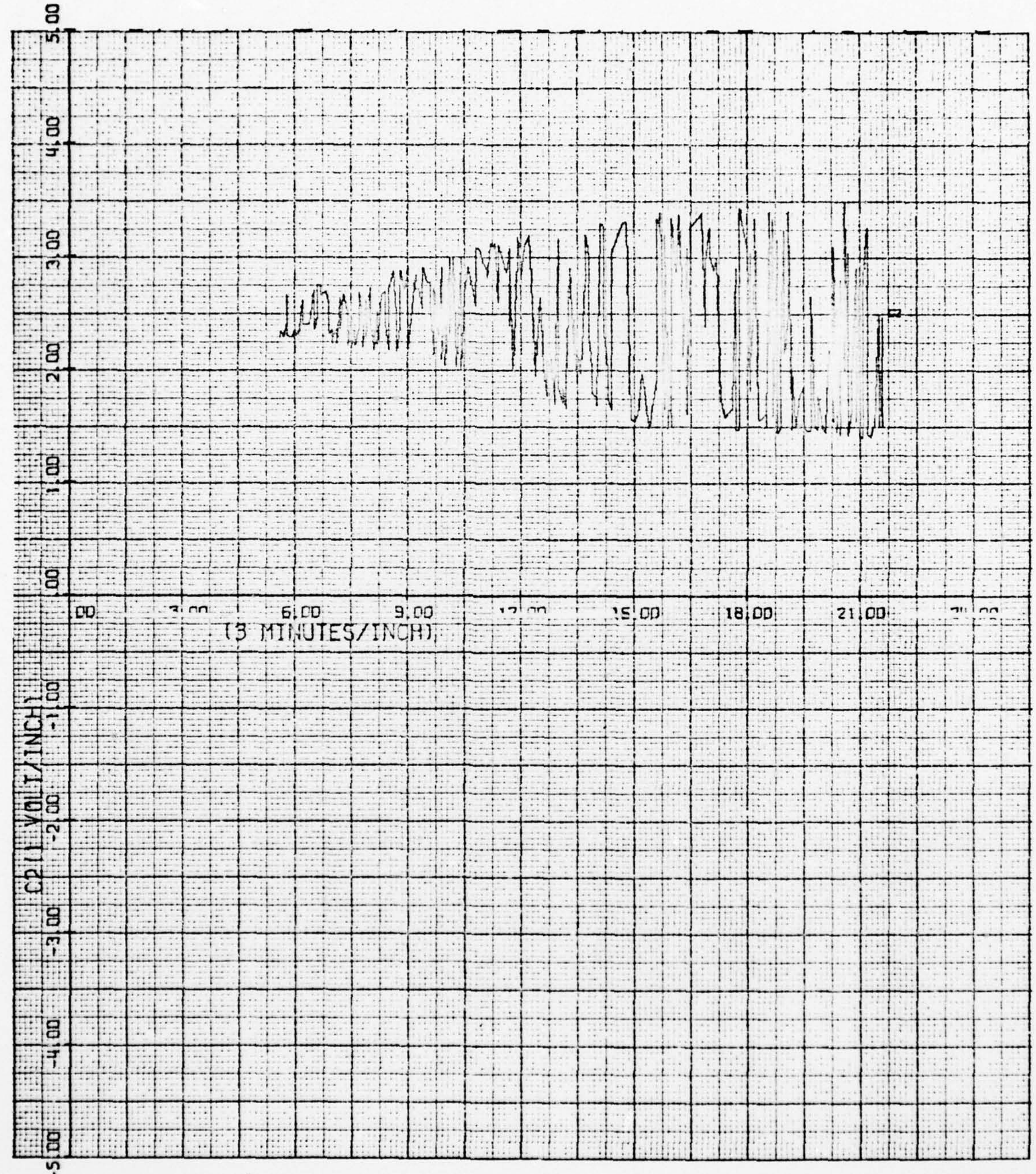

Figure 34. CAPA Data Flight 10 -- Time 0 through 21.6

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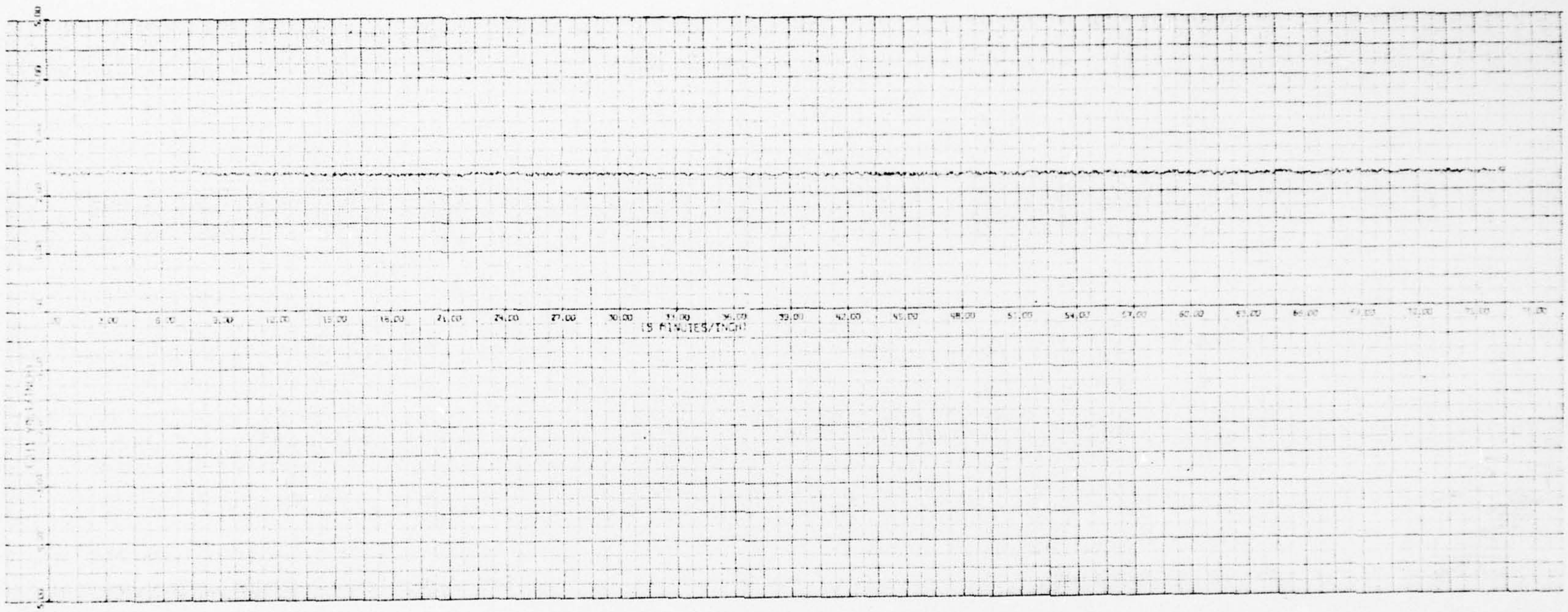

Figure 35. CAPA Data Flight 11 -- Time 0 through 78. 0

lower value at approximately +2.4 volts, and the regulator is obviously not operative, since the nominal value shifts throughout the flight to finally end at approximately +2.3 volts. Figures 36 and 37 are included to show the induced failures which were applied to C2 during flights 23 and 24. Blank spaces appeared on the IR film during the time these failures occurred. Also noticeable on Figures 36 and 37 is a continued downward drift in the nominal value of the test point.

Figure 31 shows a profile of the C2 test point for the entire demonstration test program. The value shown consists of five-minute averages of the value during each flight; the induced failures at approximately 1500 to 1600 minutes do not have even bottoms as in the individual flights 23 and 24 because the failures did not occur completely and exclusively within the five-minute averaging periods. Blank spaces on the plot indicate periods when the IR was turned off. Degradation during and following flight 8A is clearly visible on this chart. The seemingly extensive variations at 200 minutes and 1205 minutes are caused by initial turn-on conditions recorded during the final few seconds in a five-minute averaging period. Since only one or two readings are included in the average, they are not considered valid.

COMPUTER FACILITIES

The computer facilities and the extent of their use during the CAPA program are as follows:

- At a certified public accounting firm in Columbia, S.C., a Honeywell H-200 computer facility was rented and used by the CAPA field service engineer to obtain an initial data analysis of the CAPA magnetic tape. The Octal Dump and Decimal Printout programs were also available.
- At Honeywell Aerospace Division, Minneapolis, Minn., the Honeywell H-200/H-1800 computer facility was used by CAPA design personnel to perform the comprehensive data analysis of the CAPA magnetic tape. All data reduction programs were available at this facility.
- The Hybrid Simulation Facility at Honeywell, consisting of a Scientific Data Systems SDS 9300 digital computer and numerous analog computers, was used for the CAPA assembler and simulator programs.

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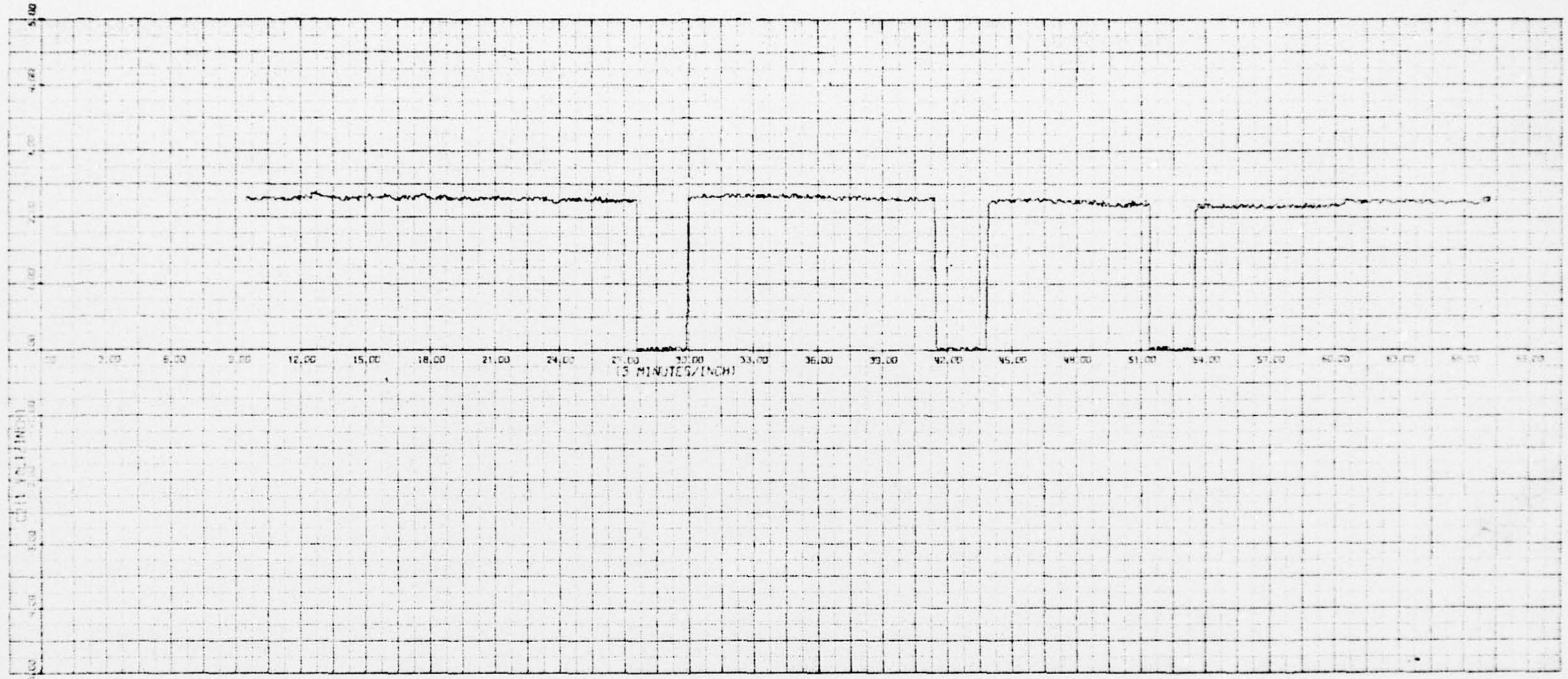

Figure 36. CAPA Data Flight 23 -- Time 0 through 67.4

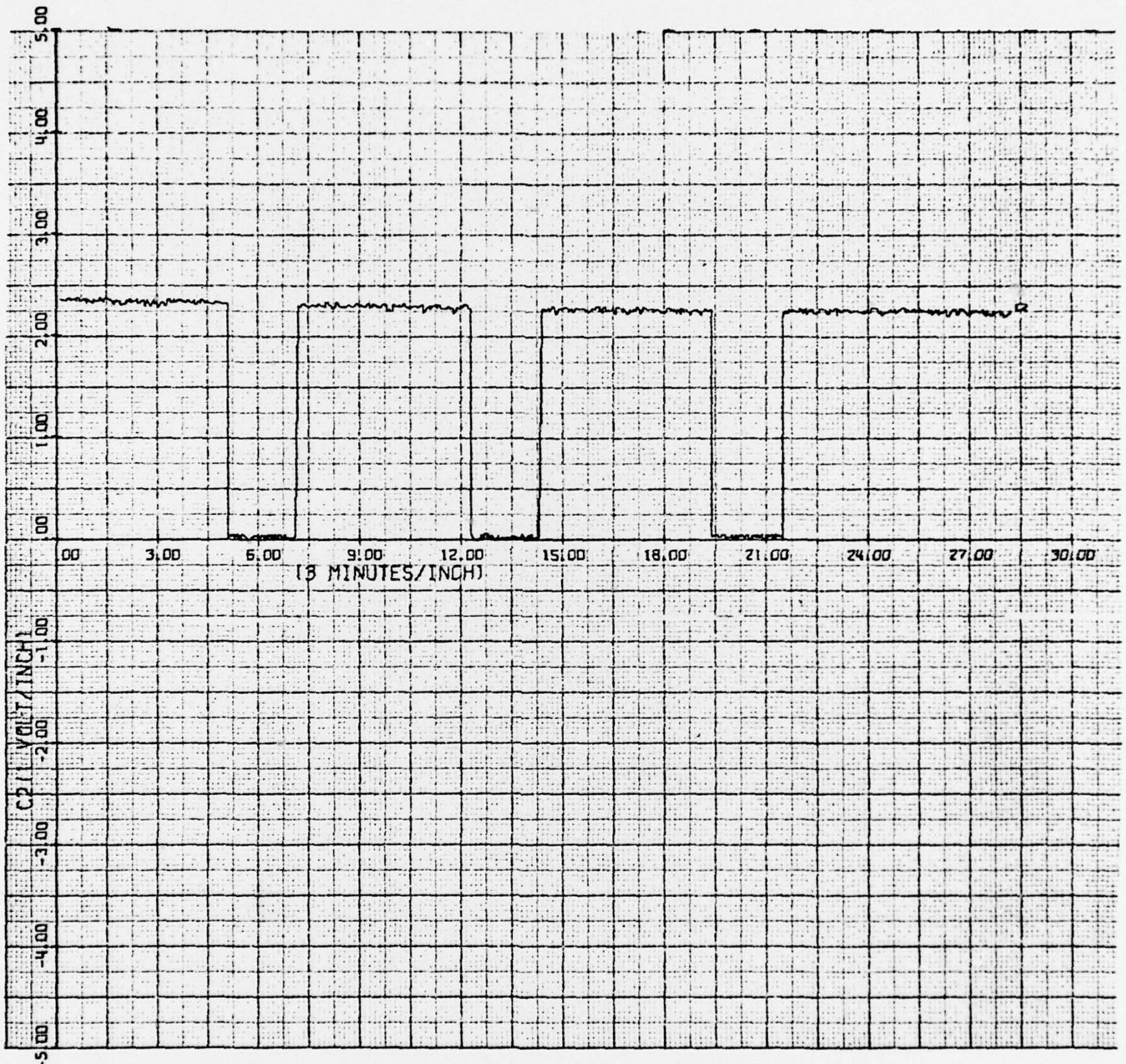

Figure 37. CAPA Data Flight 24 -- Time 0 through 56.4

APPENDIX IX

CAPA PHASE I

Extensive groundwork and preparation was necessary to ready the Central Airborne Performance Analyzer (CAPA) system for Phase II demonstration of test program objectives. The tasks involved during Phase I included:

1) CAPA System Definition -- The RF4C reconnaissance systems (SLR, IR, and KS72 camera) were analyzed to establish sensor test point availability and signficance of each test point signal. A preliminary approach to testing and monitoring each sensor was formulated. Initial GO/NO-GO (out-of-tolerance conditions) criteria were established.

2) CAPA Component Definition -- CAPA hardware preparation was based on systems definition requirements. Two new 128-test point remote units were designed. The CAPA system/aircraft sensor interface was defined. Preliminary testing procedures for each reconnaissance sensor were determined. Computing services necessary to support the CAPA program were developed. These services included the programming aids useful in developing the in-flight programs and the ground computer programs for data reduction and analysis.

3) CAPA Hardware Preparation -- The new remote units were fabricated to satisfy the previously determined requirements. The single-column printer system was designed and fabricated. The data gathering Phase I in-flight program was written. The purpose of this program was to accumulate sufficient information about each aircraft system to update and finalize the demonstration Phase II testing procedures and the GO/NO-GO criteria. This program selected all pertinent sensor test points, performed the appropriate measurement on each test point signal, and recorded each measurement result on the CAPA magnetic tape unit for post-flight data analysis. The CAPA aircraft installation plan was also developed.

4) CAPA System Test and Integration -- Functional and safety-of-flight tests were conducted in Minneapolis in accordance with the test plans. Integration bench testing was performed at Shaw AFB to provide an indication of CAPA system compatibility with actual sensor systems as they are used in the aircraft. The integration testing verified that no aircraft sensor degradation or other adverse effects due to the CAPA system existed. The CAPA system was then installed in the RF4C test aircraft and made ready for the data gathering flights.

The information and data obtained from the integration bench testing and the data gathering flights proved exceptionally useful in developing the demonstration Phase II in-flight test program. The data gathered was indicative of the dynamic operational characteristics of each reconnaissance sensor in its normal operating environment.

9 Final rept. Dec 66 - Sep 68

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Honeywell Inc., Aerospace Division 2600 Ridgway Road Minneapolis, Minnesota 55413	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP N/A
3. REPORT TITLE CENTRAL AIRBORNE PERFORMANCE ANALYZER 6	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report, December 1966 through September 1968	
5. AUTHOR(S) (First name, middle initial, last name) John E. Barker 10 William L. Kruse Gilbert J. Mros	11 Mar 69 12 101p.
6. REPORT DATE March 1969	7a. TOTAL NO. OF PAGES 102 7b. NO. OF REFS None
8a. CONTRACT OR GRANT NO. F33657-67-C-0743 b. PROJECT NO. 15 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 14 20714-FR2 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ~~ASD-TR-68-~~
10. DISTRIBUTION STATEMENT DISTRIBUTION STATEMENT A Approved for public release; Distribution Unlimited	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Aeronautical Systems Division Air Force Systems Command Wright-Patterson Air Force Base, Ohio

13. ABSTRACT

Studies have shown that significant improvements in aircraft effectiveness (availability, mission success, spares, aerospace ground equipment requirements) will result if system monitoring and fault isolation can be done in-flight during actual operation of those avionics systems which have the lowest reliabilities. The Central Airborne Performance Analyzer (CAPA) was used in this program to demonstrate the feasibility of in-flight fault isolation. The CAPA was installed in an RF4C aircraft and interfaced with the electronics systems of the side-looking radar, infrared detecting set, and KS72 camera without altering the circuitry of these systems. Data gathering missions were flown to acquire information about the signals being monitored. The CAPA was then programmed to continuously monitor the aircraft systems, detect any malfunction, isolate the malfunction to a line replaceable unit (LRU) and print the location of the malfunction along with the time of occurrence. In short, the CAPA produces an easily understood maintenance message which is available to the flight line crew immediately upon aircraft landing, without the use of flight line aerospace ground equipment or any ground data processing. Data developed during the test program proved the technical feasibility and showed that the application of CAPA to RF4C reconnaissance systems would increase the aircraft's effectiveness by 30 percent through increased aircraft availability and a greater number of successful missions.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Central Airborne Performance Analyzer (CAPA)						
feasibility demonstration						
in-flight fault isolation						
RF4C aircraft						
electronic systems						
interface with CAPA						
side-looking radar						
infrared detecting set						
KS72 camera						
data gathering flights						
detect malfunction						
isolate malfunction						
line replaceable unit (LRU)						
maintenance message						
printout						
immediate availability of message to flight line crew						
program test data						
technical feasibility proved						
aircraft effectiveness increased 30 percent						